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# THESIS

VIBRATION ISOLATION OF A MICROPHONE

by

Charles Douglas Stehle

September 1985

Co-advisors:

S. L. Garrett  
O. B. Wilson

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Vibration Isolation  
of a  
Microphone

by

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Commander, United//States Navy  
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Submitted in partial fulfillment of the  
requirements for the degree of

MASTER OF SCIENCE IN ENGINEERING ACOUSTICS

from the

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September 1985

## ABSTRACT

A microphone vibration isolation system using a bungee elastic suspension, designed for use in a system (NASA Project G-313) to measure the ambient noise in the Space Shuttle's payload bay during launch is described. The isolator's transmissibility was measured using a computer controlled shaker table system programmed to simulate the Shuttle's vibrational spectrum in 21 third octave bands between 20 and 2000 Hertz. Static deflection and transient response measurements verified the axial and radial transmissibility measurements. Free decay measurements were made at 5, 20, and 65 °C. The isolator's natural frequency of 15 Hertz represents a substantial improvement over the isolator used previously whose lowest resonance was above 100 Hertz. Test procedures and calibration data for three microphones are included.

## THESIS DISCLAIMER

The reader is cautioned that computer programs developed in this research may not have been exercised for all cases of interest. While every effort has been made, within the time available, to ensure that the programs are free of computational and logic errors, they cannot be considered validated. Any application of these programs without additional verification is at the risk of the user.



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## I. INTRODUCTION

### A. BACKGROUND

This thesis presents information on the development of a system to individually isolate three Endevco Model 2510 Transducers (microphones) from structure borne vibrations existing in the Space Transportation System (STS) Orbiter Vehicle's payload bay. Procedures for calibrating the microphones are also presented. The isolated microphones will be used to measure the acoustic characteristics of the payload bay as part of NASA Project G-313. The project was conceived from concern that earlier payloads may have been and future payloads may be damaged by airborne noise. The experiment will measure acoustic characteristics of the payload bay before and during launch. Results should be useful in predicting the acoustic environment in the payload bay.

During liftoff and atmospheric flight acoustic energy will be generated by:

- airflow over the airframe,
- main engine and solid rocket boosters, and
- airflow into and out of the bay through vents.

If the frequencies of these sources coincide with frequencies of resonance within the payload bay, acoustic levels inside the payload bay will be amplified. These frequencies and energy levels will be of particular concern. A resonance may occur in the payload bay if the acoustic wavelength at a source frequency is related to the dimension of the bay. For example, by assuming the payload bay to be a right circular cylindrical cavity with perfectly rigid boundaries the trapped energy will not be able to escape. The energy density will increase until the rate of energy losses at the boundaries, or in the medium, equals the rate



acoustic energy is being generated. If wavelengths of the source are related to the dimensions of the cavity by integer or Bessel multipliers then a resonance may be excited in the cavity. Standing waves at these wavelengths and resonant frequencies will have greatly magnified pressure magnitudes and the pressure of any resulting acoustic waves may be large enough to have the potential to damage payloads.

The acoustic characteristics of the payload bay will be determined in three phases:

1. Prelaunch. The normal modes of the payload bay will be studied by exciting the standing waves of the bay's resonant frequencies with a loud speaker and swept tone from 18 to 1024 Hertz.
2. Launch. Acoustic pressures and frequencies will be measured and recorded for the first 10 seconds of flight.
3. Post Flight. Launch frequencies will be compared to prelaunch resonant frequencies in an effort to isolate source frequencies from payload bay resonant frequencies. An attempt will then be made to determine the source of tones recorded during launch.

This analysis of frequencies, pressure magnitude, and source will be useful in determining structural requirements for future shuttle payloads.

#### B. PREVIOUS ACOUSTIC MEASUREMENTS

Earlier NASA directed studies of the payload bay acoustic properties used analytical models and recorded flight data. The analytical model predicted the payload bay acoustic environment for a given exterior acoustic field. The payload bay was modeled with and without payloads and in each case with and without sound absorbing materials on the bulkheads. The Payload Acoustic Environment for Shuttle (PACES) computer program and a one-quarter scale model were

used to determine the effect of payloads on the payload bay acoustic environment. These tests predicted that the magnitude of pressure waves would increase as dimensions of the payload increased [Ref. 1].

Actual vibro-acoustic data have been acquired and reported by the NASA Dynamic, Acoustic, and Thermal Environment (DATE) Activity. This data base consists of data recorded on DATE instrumentation, and the Development Flight Instrumentation system. Instrumentation included low and high frequency accelerometers on STS flights Two through Five, and microphones and high frequency accelerometers on STS flight Nine. Results indicated that the pressure equalization vents were a source of discrete frequency components between 280 and 340 hertz, with some tones at sound pressure levels high as 134 dB (re 20  $\mu$ Pa), [Ref. 2 : pp. 3, 17].

#### C. DEFICIENCIES IN EARLIER DATA

As reported in [Ref. 2 : p. 79], DATE activity noted data deficiencies include :

- lack of data from the foreward one-third of the payload bay,
- lack of data on transonic acoustic environment due to vent noise,
- unknown effects of launch vehicle configuration and changes in payload,
- unknown effects of launch site pad and terrain at Kennedy Space Center and Vandenberg Launch Site,
- possible error in microphone data due to mounting close to bulkhead and housing the microphone in a partial enclosure, and
- possible misinterpretation of DATE microphone data due to interaction of the microphone and the isolation system.

#### D. PREVIOUS MICROPHONE VIBRATION ISOLATOR

Since this is a report on the development of a new microphone mounting, a comparison with the mount used in earlier noise measurement is of interest. Because the previously used mount was not available estimates of its properties were obtained from a photograph, some material properties, and simple vibration isolator design theory. Figure 1.1 shows a Goddard Space Flight Center vibration isolated microphone used to gather acoustic data on a previous STS flight. The isolation system consists of a fixed-free mass loaded bar. The masses are a microphone and an equivalent mass, both attached to mounting plates which are affixed to a silicone rubber material that acts as a complex spring to provide a restoring and damping force. The resonant frequency was estimated using measurements taken from the photograph.

- Photo scale, .7 mm = 1 cm
- One mounting plate, 5 x 1.5 x .4 cm
- One mounting plate, aluminum, density = 2.7 gr/cm<sup>2</sup>
- One mounting plate, mass ,M<sub>p</sub> = 8 grams
- One rubber isolator pad,L,W,t = 1.5 x 1.5 x .5 cm
- One rubber pad, mass M<sub>i</sub> = negligible
- Rubber pad Durometer A30, shear modulus G = 3.5 x 10<sup>5</sup> Pascal
- Loss tangent = unknown
- One microphone, mass, M<sub>m</sub> = 60 grams

Based on the shear modulus of elasticity, the effective Young's modulus stated in [Ref. 3 : p. 3] for one isolating pad is

$$E_{\text{eff}} = (1 + \beta S^2) 3G \quad (1.1)$$

where for a rectangular pad

$$\beta = 2 \quad (1.2)$$



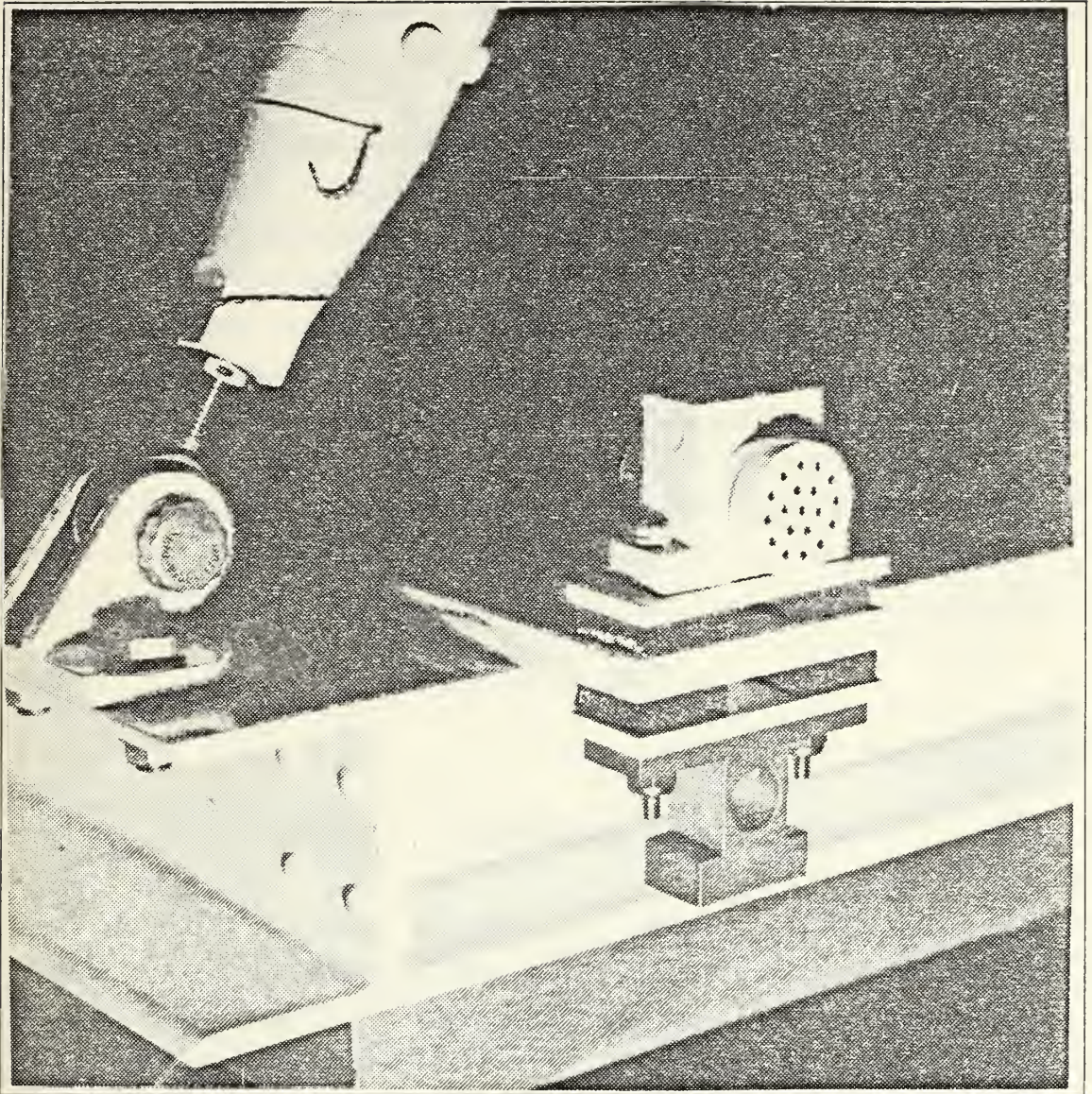


Figure 1.1 Microphone and GSFC Mount

and

$$S = \frac{\text{Area of one loaded face, } A = L W}{\text{total unloaded surface area, } 2(L t + W t)} \quad (1.3)$$

yielding

$$E_{\text{eff}} = 22 \times 10^5 \text{ Pascal} \quad (1.4)$$



Using this effective modulus, an equivalent compression stiffness may be calculated:

$$k_{\text{single pad}} = \frac{AE_{\text{eff}}}{t} \quad (1.5)$$

where 'A' is the area of one loaded surface and 't' is the distance between loaded surfaces. Thus

$$k_{\text{compression}} = 2k_{\text{single pad}} = 200 \times 10^3 \text{ N/m} \quad (1.6)$$

A resonant compression frequency is then calculated using the well known equation:

$$f_{\text{compression}} = \frac{1}{2\pi} \sqrt{k_{\text{compression}} / (M_m + M_p)} = 270 \text{ Hertz} \quad (1.7)$$

Similarly, for shear, the stiffness is:

$$k_{\text{shear}} = \frac{Glw}{t} = 35 \times 10^3 \text{ N/m} \quad (1.8)$$

and

$$f_{\text{shear}} = \frac{1}{2\pi} \sqrt{k_{\text{shear}} / (M_m + M_p)} = 110 \text{ Hertz} \quad (1.9)$$

As discussed in Part II, Theory, this implies that the isolator was, in fact, an amplifier in the frequency ranges of interest. In a recent contractor analysis of the isolator [Ref. 4 : pp. 1-3], resonant frequencies were measured to be approximately 100 Hertz in compression, and shear.

#### E. GET AWAY SPECIAL CONTAINER (GAS CAN)

Apparatus to measure and record the payload bay vibro-acoustic data is mounted in a GAS CAN, which in turn will be mounted on the forward bulkhead of the shuttle payload bay (Figure 1.2). The G-313 GAS CAN, is a standard five cubic foot cylindrical container, with a specially modified outer lid, and an additional specially fabricated inner pressure

lid. The GAS CAN described in [Ref. 5 : p. 12] is made of aluminum throughout, and pressurized to maintain about one atmosphere of pressure. The standard lid was modified to house the three microphone isolation units, a speaker, and a Helmholtz tube illustrated in Figure 1.3.

The inner pressure lid is an eight-inch deep flanged cap that mounts below the outer lid, and encloses the loud speaker sound source and three microphones mounted on the outer lid. This inner lid provides the pressure seal for all contents not mounted on the outer lid. Details of the electronic package, bubble memory unit, and power supply shown are discussed in other NPS Theses that support Project G-313. The mounting of these units in the GAS CAN is illustrated in Figure 1.4.

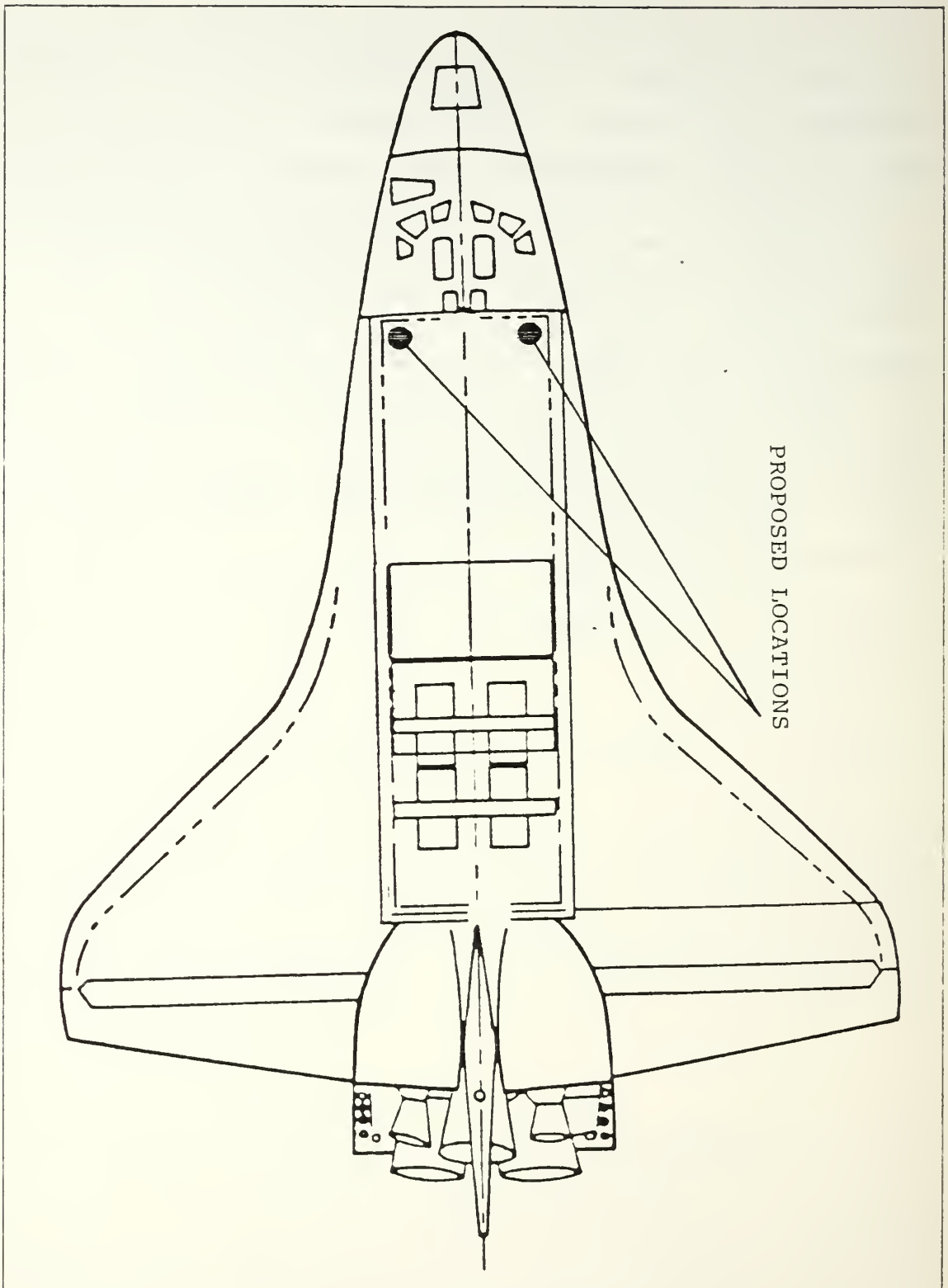


Figure 1.2 GAS CAN Location in Payload Bay







## II. THEORY

### A. ISOLATION REQUIREMENTS

Figure 2.1 shows the maximum acceleration spectral density from random structure borne vibrations to which GAS payloads may be exposed. [Ref. 5 : p. 57]. These vibratory loads can interfere either constructively or destructively with airborne acoustic signals.

The specification for the vibration sensitivity of the model 2510 ENDEVCO microphone is the equivalent of 105 dB SPL, (re 20  $\mu$ Pa), at one peak g. Based on the vibration spectrum, the microphones will be exposed to a peak acceleration of at least 7.5g. This results in an equivalent acoustic level of 123 dB SPL, a level that would be significant if purely acoustic.

RMS acceleration (g loads) for one third octave band center frequencies,  $f_c$ , were derived from figure 2.1 by first computing the bandwidth (BW), and then computing the g load:

$$BW = f_c(2^{1/3} - 1)2^{-1/6} \quad (2.1)$$

and for frequencies between 20 and 80 Hertz :

$$g \text{ load} = \sqrt{.125(BW)(f_c)/80} \quad (2.2)$$

between 80 and 1000 Hertz:

$$g \text{ load} = \sqrt{.125(BW)} \quad (2.3)$$

and between 1000 and 2000 Hertz:

$$g \text{ load} = \sqrt{.125(BW)(1000)/f_c} \quad (2.4)$$

Table I lists the equivalent single frequency RMS g loads for one third octave band frequencies from 20 to 2000 Hertz and the corresponding bandwidths. The response of the

# SHUTTLE ENVIRONMENT

RANDOM  
VIBRATION

ACCELERATIONS  
QUASI-STEADY STATE  
LIMIT LOAD FACTORS

ACROSS  
CONTAINER =  $\pm 6.0 \text{ g's}$   
AXIS (ALL  
DIRECTIONS)

ALONG  
CONTAINER =  $\pm 10.0 \text{ g's}$   
AXIS

OVERALL ROOT MEAN SQUARED  
RANDOM VIBRATION LEVEL IS  
**12.9 g's**

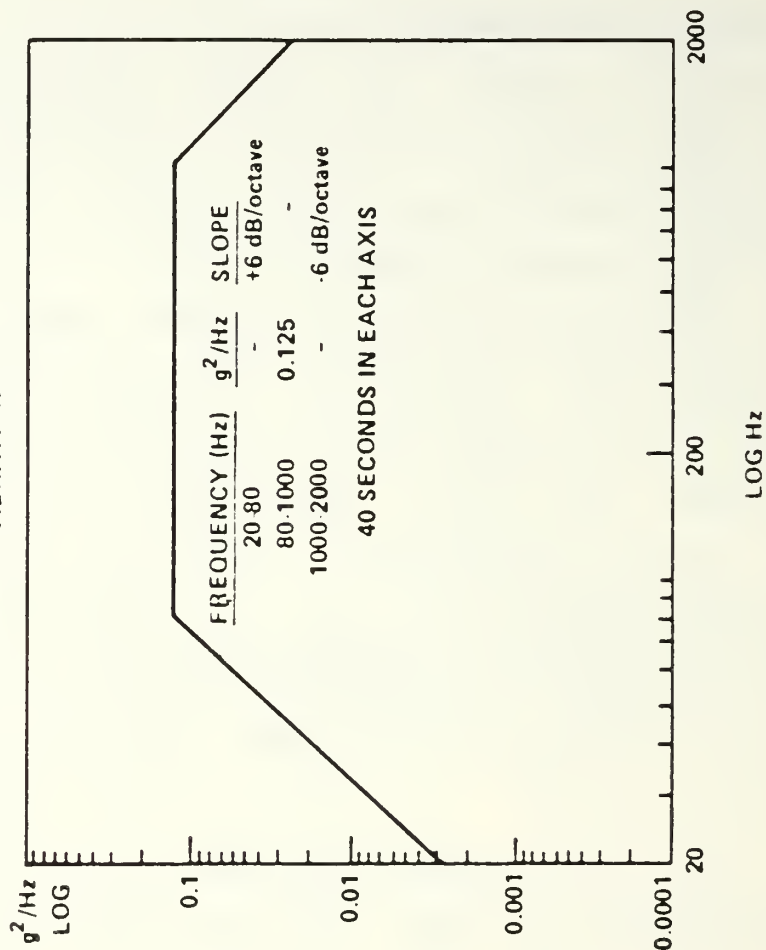


Figure 2.1 Payload Bay Random  
Vibro-Acoustic Acceleration Spectral Density

microphones to these vibration induced structural g loads may be reduced by mounting each microphone in a vibration isolation device.

TABLE I  
VIBRATION G LOADS FOR SHUTTLE PAYLOADS

FREQ (HZ)	BAND WIDTH (HZ)	G LOAD (RMS)
20.0	4.6	.38
25.0	5.8	.48
31.5	7.3	.60
40.0	9.3	.76
50.0	11.6	.95
63.0	14.6	1.20
80.0	18.5	1.52
100.0	23.2	1.70
125.0	28.9	1.90
160.0	37.1	2.15
200.0	46.3	2.41
250.0	57.9	2.69
315.0	72.9	3.02
400.0	92.6	3.40
500.0	115.8	3.80
630.0	145.9	4.27
800.0	185.3	4.81
1000.0	231.6	5.38
1250.0	289.5	5.38
1600.0	370.5	5.38
2000.0	463.1	5.38

#### B. SINGLE DEGREE OF FREEDOM ISOLATORS

A single degree of freedom isolator requires only one axis of a coordinate system to describe the motion. As stated in [Ref. 3 : p. 22], the equation of motion for the mass of the simple spring mass damper system with a moving foundation shown in Figure 2.2 is :

$$m\ddot{x} + c(\dot{x} - \dot{y}) + k(x - y) = 0 \quad (2.5)$$

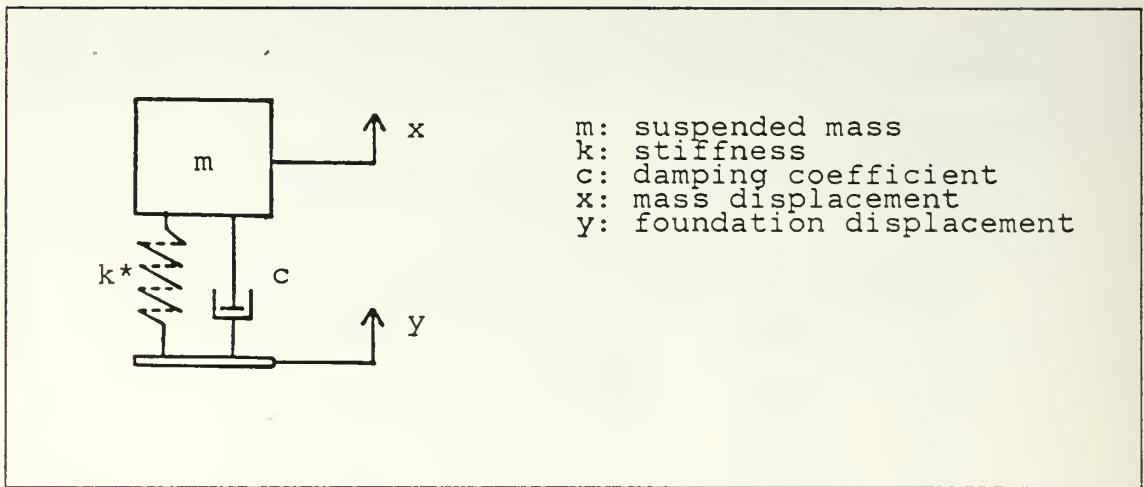


Figure 2.2 Simple Spring Mass Damper System

and if

$$z = x - y \quad (2.6)$$

and the foundation oscillates according to :

$$y(t) = Y_0 \cos \omega t \quad (2.7)$$

then

$$\ddot{z} + \frac{c}{m}\dot{z} + \frac{k}{m}z = \omega^2 Y_0 \cos \omega t \quad (2.8)$$

where

- $X_0$  is the peak amplitude of the mass's displacement
- $x$  is distance the mass is displaced
- $Y_0$  is the peak amplitude of the foundation's displacement
- $y$  is distance the foundation is displaced
- $m$  is the mass of the object supported
- $c$  is the damping coefficient
- $k$  is the real spring constant or stiffness
- $\omega_n$  is the undamped natural resonant frequency
- $\omega$  is the angular frequency of the oscillating foundation

and

$$\omega_n = \sqrt{k/m} \quad (2.9)$$

In non-dimensional form this is:

$$\ddot{z} + \xi \omega_n^2 \dot{z} + \omega_n^2 z = \omega^2 Y_0 \cos \omega t \quad (2.10)$$

where  $\xi$  is the viscous damping ratio

$$\xi = \frac{c}{c_c} \quad (2.11)$$

and

$$c_c = 2\sqrt{mk} \quad (2.12)$$

is the critical damping coefficient or that value of damping coefficient above which no oscillations occur. To solve this equation we must determine either  $\xi$  and  $\omega_n$ , or the damping coefficient and the static spring constant.

#### 1. Complex Spring Constant

Rubber materials provide both stiffness and damper characteristics, which may be represented by a complex spring constant,  $k^*$ . As developed in [Ref. 3 : p. 22] and [Ref. 6 : pp. 4.8-4.11],

$$G_u^* = G_x(1 + j\delta) \quad (2.13)$$

where  $G^*$  is the complex shear modulus of the material at frequency  $\omega$ . Then

$$k^* = kG^* \quad (2.14)$$

where  $k$ , as stated in [Ref. 3 p. 23], is a geometric factor with dimensions of length. For compression

$$k_{\text{compression}} = \frac{(1 + \beta S^2) 3 A}{t} \quad (2.15)$$

and for shear

$$k_{\text{shear}} = \frac{A}{t} \quad (2.16)$$

$A$ ,  $\beta$ ,  $S$  and  $t$  are as described in equations 1.2, 1.3, 1.5.  $\delta$ , the loss tangent, is the ratio of the imaginary to real modulus as shown in Figure 2.3.

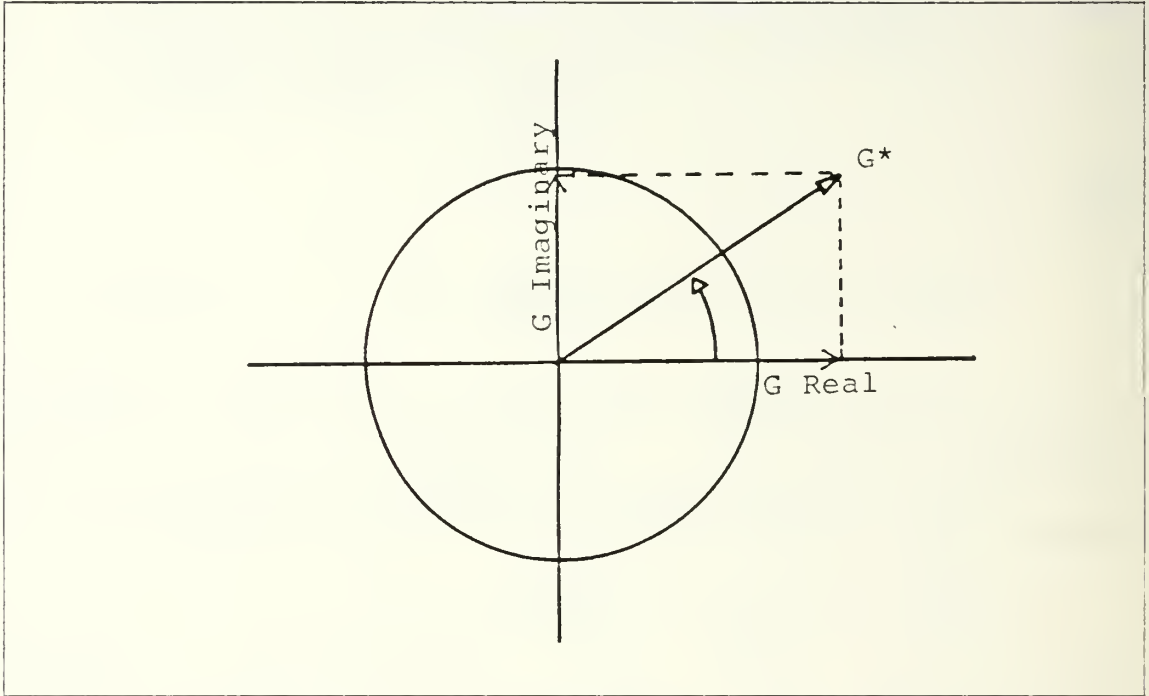


Figure 2.3 Complex Modulus of Elasticity

$\delta$  is also referred to as the loss factor and in many materials may be a function of frequency. It can be shown that for  $\xi < .3$  that  $\delta = 2\xi$  [Ref. 3 : p. 3] Figure 2.4 is a simple system using a complex spring.

## 2. Viscous Damping Ratio

The solution to the homogenous equation of motion for the case where  $\xi < 1$  is a damped sinusoid that oscillates at the damped resonant frequency  $\omega_d$  and decays exponentially from the initial displacement according to :

$$x(t) = X_0 e^{-\xi \omega_n t} \sin(\omega_d t + \phi) \quad (2.17)$$



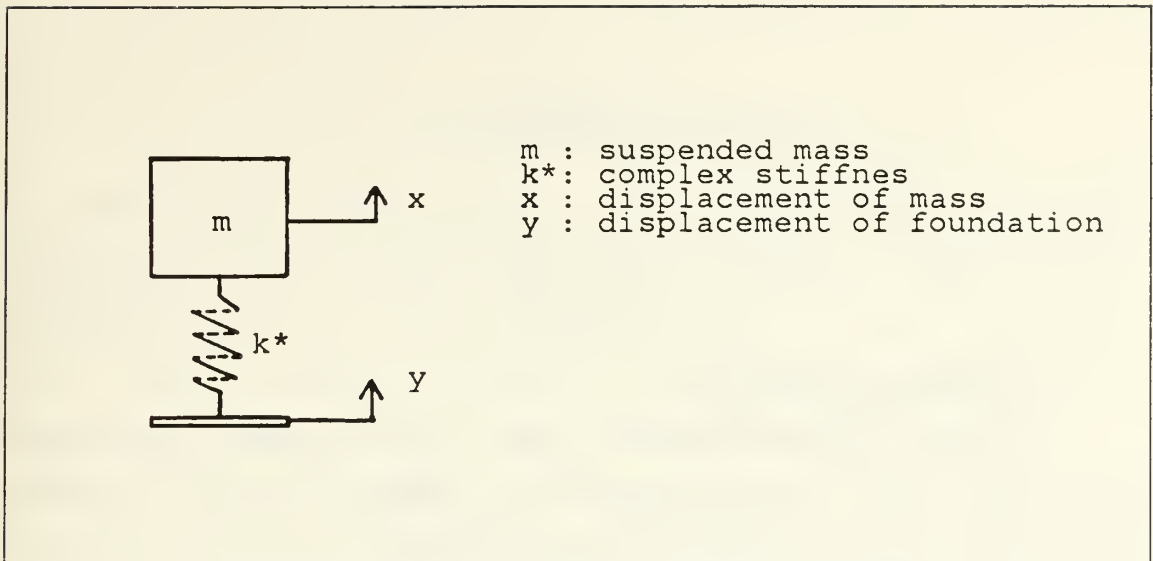


Figure 2.4 Complex Spring System

This represents the free vibrations of a damped system. The degree of damping,  $\xi$ , may be determined experimentally by logarithmic decrement techniques. The log decrement,  $\Delta$ , is the natural logarithm of the ratio of amplitudes of two successive cycles of the damped free vibrations:

$$\Delta = \ln \frac{x_1}{x_2} \quad (2.18)$$

where

$$x_1 = X_0 e^{-\xi \omega_n t} \quad (2.19)$$

and

$$x_2 = X_0 e^{-\xi (\omega_n t + 2\pi)} \quad (2.20)$$

then

$$\frac{x_1}{x_2} = \frac{X_0 e^{-\xi \omega_n t}}{X_0 e^{-\xi (\omega_n t + 2\pi)}} \quad (2.21)$$

this reduces to

$$\frac{x_1}{x_2} = e^{\xi 2\pi} \quad (2.22)$$

so that

$$\Delta = \ln e^{t^2} \quad (2.23)$$

thus

$$\xi = \frac{\Delta}{2\pi} \quad (2.24)$$

### 3. Transmissibility

The isolation system will be excited by shuttle vibrations that are equivalent to either a time variable force  $F(t)$  or displacement  $y(t)$  acting on the base of the microphone isolator. In either case, the transmissibility  $\epsilon(\text{dB})$  as developed in [Ref. 7 : p. 80] and [Ref. 3 : p. 27] will be :

$$\epsilon_{(\text{dB})} = 20 \log \frac{\text{Force transmitted to microphone}}{\text{Force applied to base}} = 20 \log \frac{x}{y} \quad (2.25)$$

For the viscous damper the transmissibility is

$$\epsilon_{(\text{dB})} = 10 \log \frac{1 + (2\xi \frac{\omega}{\omega_n})^2}{\{1 - (\frac{\omega}{\omega_n})^2\}^2 + (2\xi \frac{\omega}{\omega_n})^2} \quad (2.26)$$

and for the complex spring it is

$$\epsilon_{(\text{dB})} = 20 \log \left[ \frac{1 + \delta_\omega^2}{\left\{ 1 - \left( \frac{\omega}{\omega_n} \right)^2 \frac{G_0}{G_\omega} \right\}^2 + \delta_\omega^2} \right]^{1/2} \quad (2.27)$$

where  $\omega$  is the operating frequency. For a rubber of Type I, [Ref. 3 : p. 27], the loss tangent is about .1 ,the shear modulus is independent of frequency and

$$G_0 = G_\omega \quad (2.28)$$

The isolators discussed in this report were analyzed using both viscous and complex models. The results are compared in Chapter IV.

### III. EXPERIMENTAL APPARATUS

Experiments to measure the microphone's vibration response, and the transmissibility of the isolation systems employed a shaker table, a wave form generator, dual channel spectrum analyzer, two low noise preamps, three accelerometers, and an anechoic chamber. Microphone calibration and comparison, free decay, and environmental tests did not require the shaker table. A computer controlled interactive program was written to drive the shaker table and record results. Figure 3.1 is a block diagram of the apparatus as well as lines of control and information flow. A copy of the program is in Appendix A.

#### A. VIBRATION EXPERIMENTS

Vibration experiments were performed to determine the response of the microphones to vibration and the transmissibility of the isolation system.

##### 1. Shaker Table

The Model 120-S PERMA DYNE Shaker Table was the primary experimental apparatus. The unit is an electrodynamic shaker that was used to produce sinusoidal acceleration wave forms. The force generated by the shaker was proportional to the instantaneous current supplied by the APS Model 114 Power Amplifier. The shaker used a symmetrical permanent magnet circuit for maximum force/current linearity and minimum stray field. The shaker table was used to vibrate both the microphones, and the vibration isolation system at the one-third octave band frequencies and g loads listed in Table I. Microphones were vibrated radially in both the X and Y lateral directions across the face of the microphone and in the axial, or Z longitudinal, direction perpendicular to the face of the microphone. The

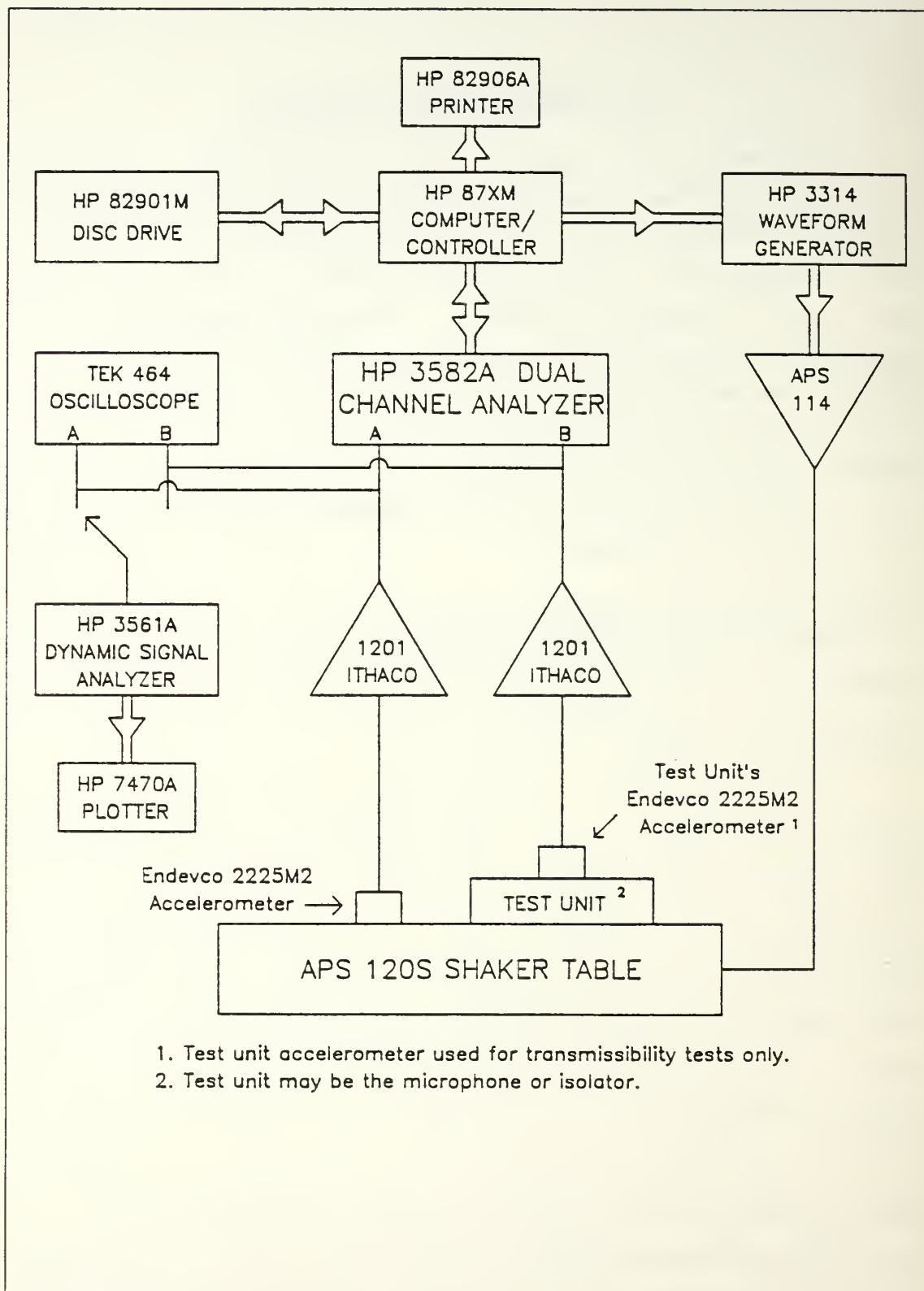


Figure 3.1 Experimental Apparatus

isolation system was vibrated in the radial (X lateral) and axial (Z longitudinal) directions.

## 2. Preamplifiers

Two low noise ITHACO amplifiers amplified the microphone and accelerometer output voltages by a factor of 100 during shaker table tests and by 10 during free decay tests. A bandwidth was selected to pass frequencies between 3 and 3000 Hertz during shaker tests and between 3 and 30 Hertz during free decay tests. The preamps were always operated on "BATTery" to reduce electronic noise. Line losses to the preamps were accounted for in the control program by using voltage divider techniques on the circuit shown in Figure 3.2.

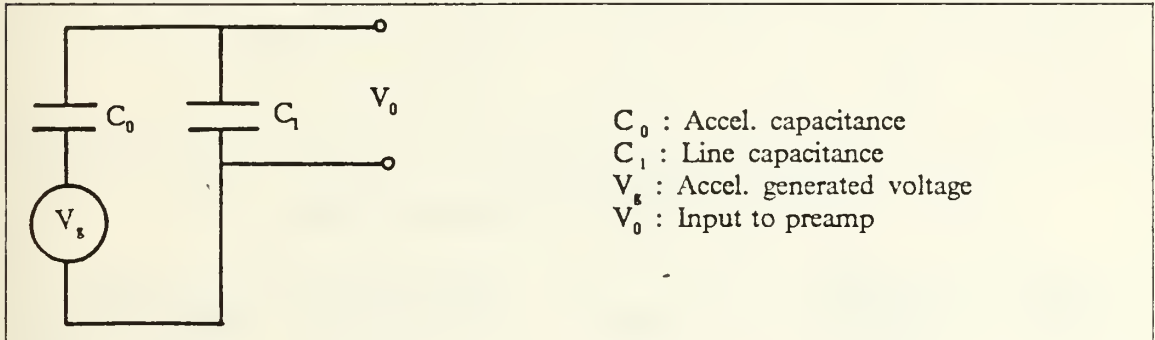


Figure 3.2 Microphone-Amplifier Circuit

The acceleration sensitivity was determined using the manufacturer's charge sensitivity and capacitance as follows:

$$\frac{1}{m} = \frac{V}{g} = \frac{Q/g}{C} = \frac{.717 \text{ pC/g}}{830 \text{ pf}} = 8.64 \times 10^{-4} \text{ V/g} \quad (3.1)$$

so that

$$m = 1158 \text{ g/V} \quad (3.2)$$

Applying the voltage divider equation the voltage due to acceleration ( $V_g$ ) is determined:

$$V_g = \left( \frac{C_s + C_1}{C_s} \right) V_0 = 1.398 V_0 \quad (3.3)$$

then the accelerometer's acceleration or g load is

$$a = V_g m = 1.398 V_0 (1158 \text{ g/V}) = 1618 V_0 \quad (3.4)$$

### 3. Accelerometers

Three ENDEVCO Model 2225M2 accelerometers were used to determine the shaker table g load, isolated microphone replica g loads, and to measure the amplitude and frequency spectrum during free decay tests of the vibration isolation system. The specifications for each accelerometer are in Table II.

TABLE II  
ACCELEROMETER SPECIFICATIONS

Serial Number	Charge Sensitivity (pC/g)	Capacitance (pF)	Transverse Sensitivity (% max)	Voltage Sensitivity (mV/g)*
FD 95	.717	830	.8	.618
FA 27	.728	820	.7	.633
FA 15	.717	792	.7	.639

\*Includes line loss capacitance = 308.3 +/- 7.5 pf.

### 4. Oscilloscope

A Tektronix Model 464 Oscilloscope was used to monitor the shaker table and test item accelerometer output wave forms for erratic behavior. The oscilloscope was not computer controlled.



## 5. Computer Controlled Apparatus

An HP-87XM desk top computer was used to control frequency and voltage inputs to the shaker amplifier, and to obtain the required g load from the shaker table. At the required g load the computer controlled equipment measured, recorded, and printed the microphone output voltage response, or isolator transmissibility, and test item data. Figure 3.3 is a sample printed output.

### a. Hewlett-Packard HP-87XM

The HP-87XM Series 80 Personal Computer contains 124K bytes of memory, and was fitted with Input/Output and Plotter ROM's. Mass storage and printed output were provided via HP-IB connections to an 82190A Flexible Disc Drive (two drives), and an HP-82906A Printer, respectively.

### b. Hewlett-Packard HP 3314A Function Generator

The Function Generator was used to provide continuous sine waves to the shaker amplifier at frequencies and voltages controlled by the HP-87XM via the HP-IB.

### c. Hewlett-Packard HP3582A Spectrum Analyzer

The HP-3582A is a dual channel spectrum analyzer that provides simultaneous frequency and voltage analysis of dual inputs. It was controlled via the HP-IB from the HP-87XM to take four samples of the accelerometer voltage measuring shaker table loads, then measure the RMS average amplitude of this voltage. If, based on manufacturer's calibration and line losses, the accelerometer voltage corresponded to the required g load, the computer directed the analyzer to read the output voltage of the test item at that frequency. If the g load was too low or too high a corresponding linear adjustment of the function generator's output voltage was made and the entire process repeated. Required g load tolerance was selected interactively.

Channel A read shaker table g load voltage, and Channel B read test item voltages. In the dual channel

# ITEM RESPONSE TO VIBRATION

VIBRATION IS PARALLEL TO THE FACE OF ITEM; Y LATERAL AXIS

ITEM NAME: MICROPHONE  
 MANUFACTURER: ENDEVCO  
 PART NO.: GC1346742-11-031  
 SERNO: BJ66  
 DATA FILE NAME: YBJ6611:D701  
 DATA DISC LABEL: C

FREQ (HZ)	ITEM VOLTS (uV)	SPL/ XMISS (DB)	INPUT VOLTS (MV)	ACCEL VOLTS (MV)	REQ'D G LOAD (G's)	OBS G LOAD (G's)	NO. TRIES
20.0	4.0	79.39	303.0	.234	.38	.38	3
25.0	2.4	75.16	227.0	.297	.48	.48	3
31.5	7.0	84.34	156.0	.370	.60	.60	2
40.0	11.9	88.92	97.9	.470	.76	.76	2
50.0	10.1	87.50	97.7	.587	.95	.95	2
63.0	10.1	87.50	166.0	.735	1.20	1.19	3
80.0	12.8	89.56	272.0	.932	1.52	1.51	2
100.0	11.9	88.92	359.0	1.050	1.70	1.70	3
125.0	12.5	89.35	441.0	1.170	1.90	1.89	2
160.0	11.9	88.92	541.0	1.320	2.15	2.14	2
200.0	20.4	93.60	636.0	1.480	2.41	2.39	2
250.0	60.4	103.03	735.0	1.650	2.69	2.67	2
315.0	85.4	106.04	755.0	1.870	3.02	3.03	2
400.0	58.9	102.81	853.0	2.100	3.40	3.40	2
500.0	59.2	102.86	920.0	2.350	3.80	3.80	2
630.0	63.2	103.43	938.0	2.640	4.27	4.27	2
800.0	69.0	104.19	848.0	2.980	4.81	4.82	2
1000.0	61.6	103.20	584.0	3.340	5.38	5.40	2
1250.0	141.0	110.40	86.8	3.320	5.38	5.37	2
1600.0	211.0	113.90	760.0	3.320	5.38	5.37	3
2000.0	158.0	111.38	1422.0	3.330	5.38	5.39	3

OVERALL BAND SPL: 118.2 DB. REF LEVEL 4.26mV @ 140 DB.

## COMMENTS:

SPL/XMISS: READ 'SPL' FOR MEASURED VOLTAGE RESPONSE.

READ 'XMISS' FOR MEASURED TRANSMISSIBILITY.

G LOADS OBTAINED WERE WITHIN 1.0% OF DESIRED VALUES.

ALL VOLTAGES ARE WITHOUT AMPLIFICATION AND INCLUDE  
 LINE LOSSES TO PREAMP.

TEST CONDUCTED IN ANECHOIC CHAMBER. Y RADIAL VIBRATIONS.

MICROPHONE UNCAPPED AND ORIENTED AWAY FROM CABLE PORTS.

Figure 3.3 Sample Computer Printout

mode, 128 bins were available for the 500 Hertz span selected and corresponded to a 7.25 Hertz bandwidth. Dual channel configurations, parameters, and specifications are shown in Table III.

TABLE III  
HP 3582A SPECIFICATIONS AND SETTINGS

	CHANNEL A	CHANNEL B
CONFIGURATION:		
Sensitivity	1 Volt	30 mVolt
Span	500 Hz	500 Hz
Passband shape	Flat top	Flat top
Number of Averages	4	4
PARAMETERS:		
Time Record Length	2 sec	
Point Spacing	4 Hz	
Equivalent Noise BW	7.24 Hz	

## 6. Free Decay Experiments

Free decay measurements of the isolation system were made to acquire independent values of the system's damped resonant frequency  $\omega_d$ , and the viscous damping ratio  $\xi$ . Decay measurements used the previously discussed ITHACO preamps and ENDEVCO accelerometers, and the following additional apparatus.

### a. Microphone Replica

A microphone replica identical in shape to the test microphone was machined from aluminum. A cutout was made on one side to house an accelerometer to measure radial vibrations. A threaded shaft was attached to the bottom of the replica to attach another accelerometer to measure axial vibrations. The replica was mounted in the isolator for axial and radial free decay and for static spring constant tests. Figure 3.4 shows the microphone and microphone replica with installed accelerometers. Total mass of the microphone replica and attached accelerometers is 47.7 grams. The actual microphone mass is 40 grams.

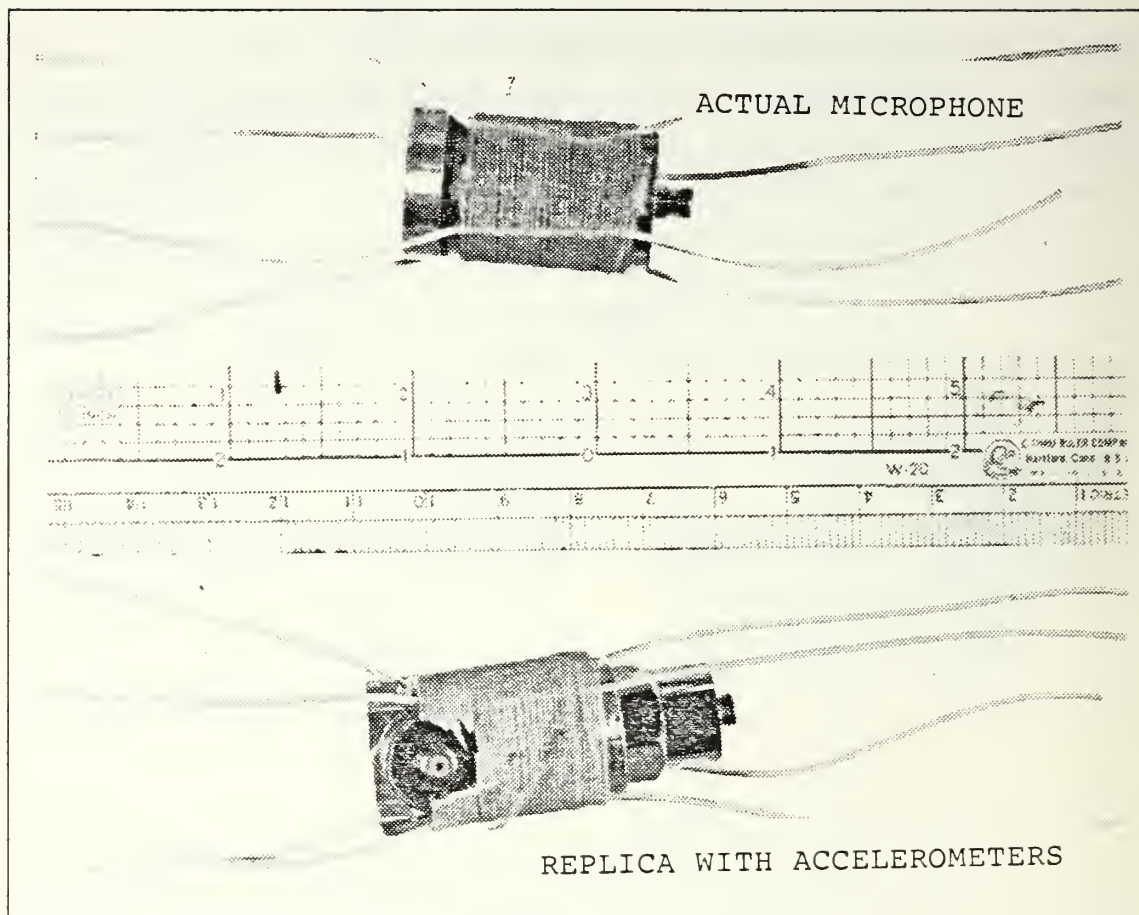


Figure 3.4 Actual Microphone and Replica

b. Hewlett-Packard 3561A Dynamic Signal Analyzer

The HP 3561A is a single-channel, Fast Fourier Transform Signal Analyzer. It is capable of measuring full scale input signals from 22.39 Vrms to 2.82 mVrms. Although it may be remotely programmable via an HP-IB, this capability was not used. The HP-IB interface was used to provide plots of the frequency and time response using an HP 7470A plotter. To obtain the free decay trace and frequency spectrum, the analyzer was operated in the manual arm, and source trigger options over a span of 100 Hertz. Resolution at this span setting was .25 Hertz. The test was conducted by orienting the isolation system to excite the microphone



shape and the selected accelerometer. The replica was gently displaced and then released. The output of the accelerometer positioned along the axis of vibration triggered the analyzer to obtain traces of the free decay and frequency response. The trace was then dumped to an HP 7470A plotter via HP-IB. Figure 3.5 shows the plotted output of a free decay test. Figure 3.6 shows the analyzer settings.

#### B. STATIC DISPLACEMENT

Radial and axial static stiffnesses for the suspension system were determined by static displacement techniques. The microphone replica was suspended in the isolating canister using the test material. A wire was tied around the replica and the free end passed through the side or bottom of the canister for radial or axial tests as appropriate. The canister was mounted on a ring stand and a ruler placed along the length of the exposed wire. A hanger was attached to a loop at the end of the wire. Weights were added to the hanger and the deflection of the replica noted. Similar techniques were used to determine the Young's modulus for a single strand of the bungee material.

#### C. MICROPHONE CALIBRATION

Calibration and comparison experiments were performed to verify the test microphone's frequency response. The first experiment compared ENDEVCO microphone serial number BJ-66 to a GenRad one half inch Electret Condenser microphone type 1560-p-42, Serial No. 4656. Table IV is performance data for the GenRad microphone. [Ref. 8 : p. v]. The second experiment compared BJ-66 to ENDEVCO microphones BJ-56 and BD-37. These experiments were conducted inside the anechoic chamber at the Naval Postgraduate School.

In each experiment, the microphones were placed immediately adjacent to each other, 24 feet diagonally across the



RANGE: -30 dBV STATUS: PAUSED

ELASTIC16 RADIAL2

A: MAG

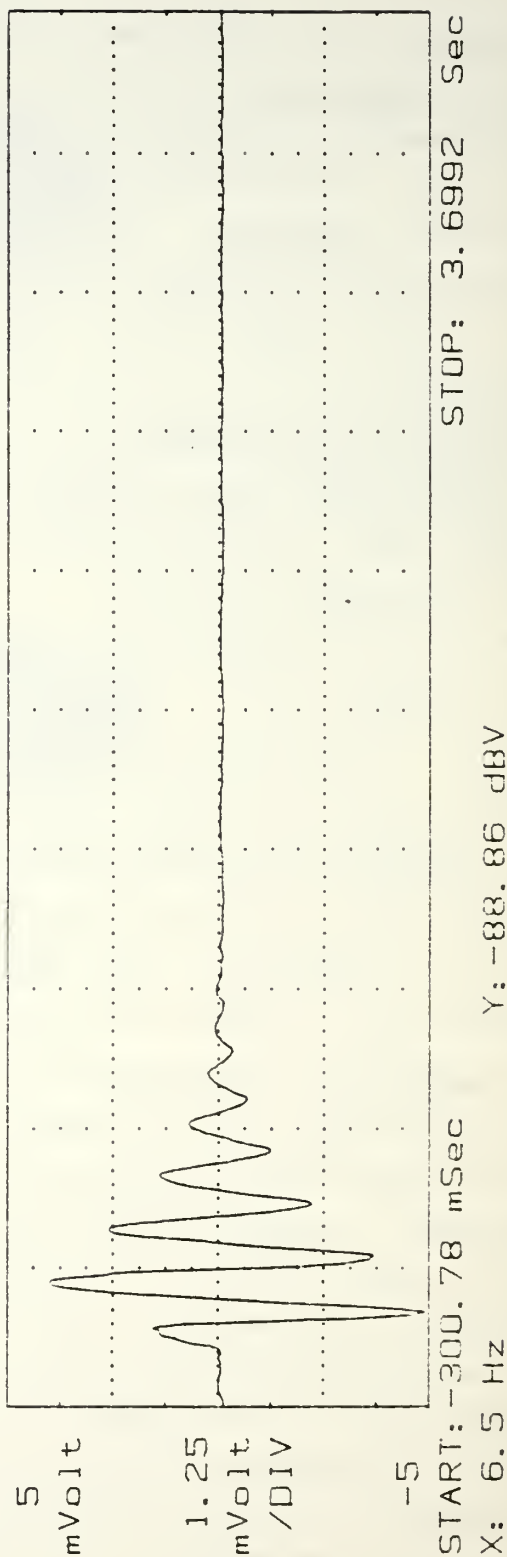
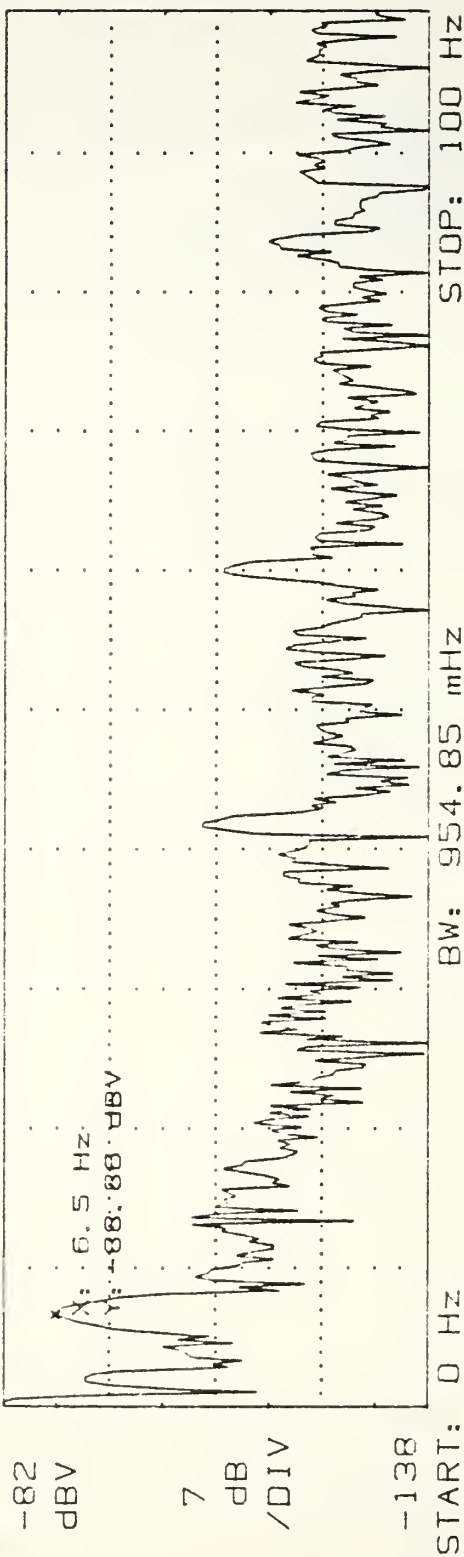


Figure 3.5 Free Decay Frequency Spectrum and Amplitude

RANGE: -20 dBV		STATUS: PAUSED
NARROW BAND MODE		
EXT SAMPLE OFF		
FREQUENCY:		
BASEBAND	START: 0 Hz	
	STOP: 100 Hz	
	TIME: 4 Sec	
TRIGGER:		
INPUT	DELAY: -300 mSec	% OF RANGE: 0 %
MANUAL ARM	POS SLOPE	
AVERAGE:		
OFF		
WINDOW:		
FLAT TOP	BW: 954.85 mHz	
SOURCE:		
OFF		
INPUT:	AC COUPLING	ICP CURRENT OFF
	AUTO RANGE OFF	AUTO CAL OFF
UNITS:		
	X: HZ	A WEIGHT FLTR OFF
	Y: dBV	CAL SIGNAL OFF

Figure 3.6 HP 3561 Analyzer Free Decay Settings

chamber from a 14 inch diameter speaker, and five feet above speaker level. An HP 3314A Function Generator was programmed to sweep from 25 to 2500 Hertz at a sweep interval of 100 msec to provide broadband excitation of the microphones. Figure 3.7 shows the output spectrum of the Function Generator.

TABLE IV  
TYPICAL PERFORMANCE OF GENRAD ELECTRET

Frequency Range (Hz)	System Sensitivity re 1 Volt/Pa	Dynamic Range* re 20 $\mu$ Pa
15 - 19K	-40 dB	30 - 145 dB

\* 'A' weighted noise level to max RMS  
sinewave signal without clipping.

Microphone response was recorded on the HP 3561A Dynamic Signal Analyzer using both linear 0-2000 Hertz and one third octave bands from 12.5 to 20,000 hertz. The results of the calibrations are presented in Chapter IV.

#### D. ENVIRONMENTAL EXPERIMENTS

Three environmental experiments were conducted to determine if temperature affected the damping and resonant frequency properties of the microphone isolation system. Tests were conducted using the microphone replica and isolation system at 5 °C and 65 °C, the expected minimum and maximum environment temperatures during launch. No significant deviations from resonant frequencies or damping ratios obtained at 20 °C were noted. The test apparatus included the microphone replica, the microphone suspension system, an insulated refrigeration unit and a hot plate. The insulated refrigeration unit was used to cool it to 5 °C and the free

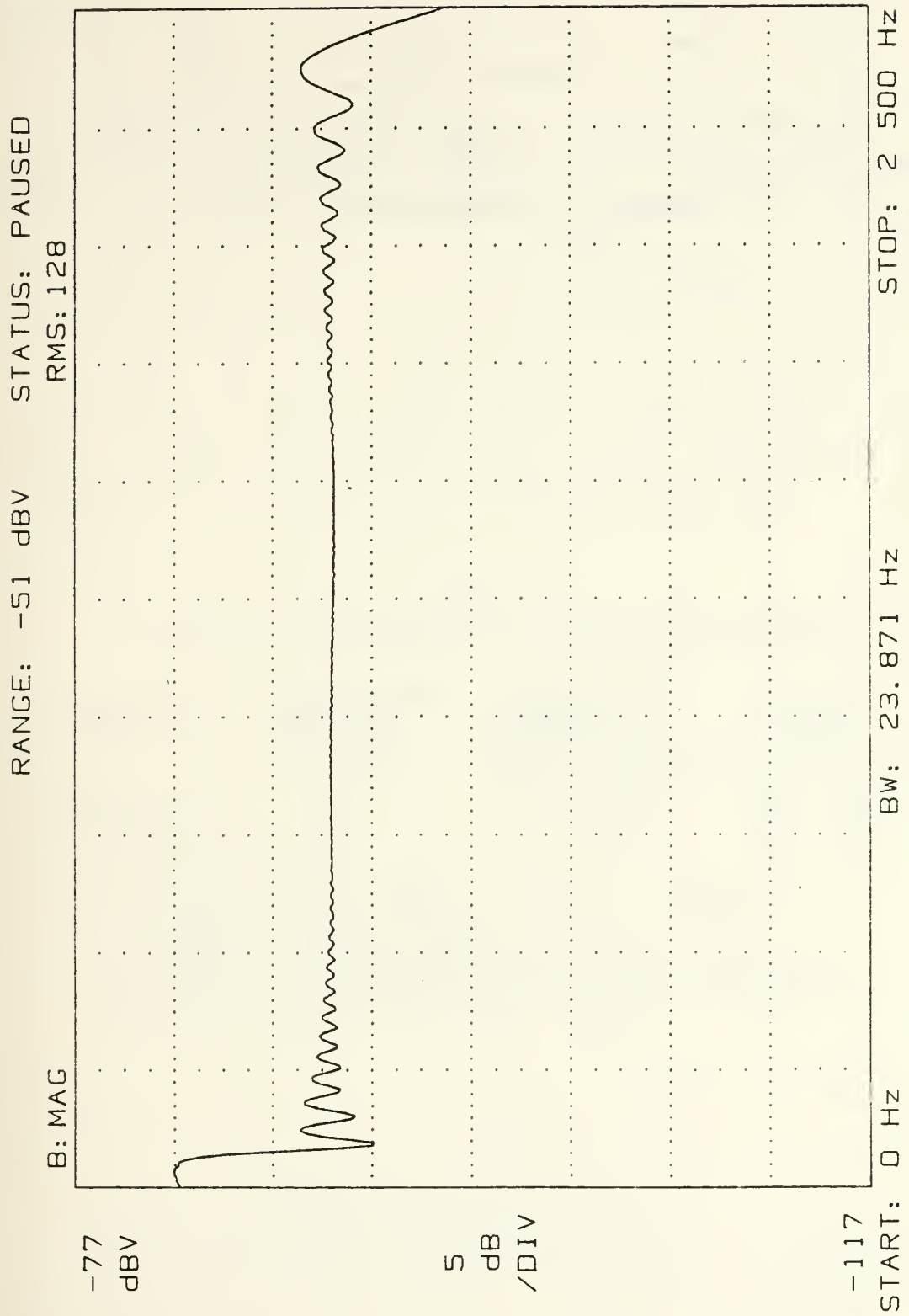


Figure 3.7 Broadband Output of Signal Source

decay noted. After securing the refrigeration unit , the hot plate was placed in the unit and at 80 °C the free decay was again tested. A low temperature test was also performed on a strand of the microphone suspension material. A 2 inch length of material was attached to the ends of two copper rods and cooled to -144°C by liquid nitrogen and then stretched a minimum of 1 inch without breaking.



#### IV. RESULTS

Triaxial vibration response data was obtained for ENDEVCO microphone serial number BJ-66. Acoustic tests were made to compare the three ENDEVCO microphones and the GenRad microphone with BJ-66. Table V summarizes the microphone vibration and noise response in the x,y,and z directions without the isolator. Radial and axial transmissibility tests were conducted on similarly constructed isolation systems using different materials: bungee cord and elastic thread. The bungee material was selected. The isolator had a resonant frequency below 15 Hertz for each axis.

TABLE V  
ENDEVCO MICROPHONE BJ-66 RESPONSE SUMMARY<sup>1</sup>

DIRECTION	EQUIVALENT <sup>2</sup>	MICROPHONE <sup>3</sup>	SHAKER <sup>4</sup>
	OVERALL SPL dB re 20 $\mu$ Pa	OVERALL dBV(RMS) re 1 Volt(20 $\mu$ Pa)	NOISE dBV(RMS)re 1 Volt(20 $\mu$ Pa)
X Lateral	117	-73 {115}	-83 {105}
Y Lateral	118	-73 {115}	-83 {105}
Z Longitudinal	126	-67 {121}	-76 {112}

1. With no amplification.
2. Microphone output when attached to shaker.
3. Microphone output as measured on HP 3561 while attached to shaker table.
4. A measure of ambient shaker noise.  
Microphone output as measured on HP 3561 while isolated from vibration but located in same position relative to shaker table.

##### A. VIBRATION RESPONSE OF BJ-66

ENDEVCO transducer serial BJ-66, P/N GC 1346742-11-031 was the primary test microphone. Figure 4.1 represents the microphone response to vibration and shaker noise, and

Figure 4.2 the response to airborne shaker noise only. One third octave band plots of internal microphone noise, shaker table noise, and both shaker vibrations and noise are shown in Figure 4.3 The overall sound pressure levels were 10 to 15 dB below those expected to exist, and the difference between vibration/noise levels and noise only levels was an average of 15 dB. This low response to vibration enhances the microphone's use for measuring acoustic pressure magnitude. The quality of the data could be improved significantly at frequencies less than 100 Hertz by developing an isolator that would lower the vibration response at least 10 dB from peak levels below 100 Hertz.

#### B. SENSITIVITY COMPARISON

Tests were conducted in the anechoic chamber to determine the sensitivity of BJ-66, and to verify that each microphone had similar acoustic response. Sensitivity tests were performed by comparing the voltage output of BJ-66 to the GenRad one-half inch Electret. [Ref. 8 : p. 27] specifies that the Electret microphone has a sensitivity of -61.8 Volts/ $\mu$ bar. Tests showed that BJ-66's average response exceeded that of the Electret by 3.2 dB as shown in Figure 4.4 The sensitivity of the ENDEVCO was then determined as follows:

$$\begin{aligned} \text{sensitivity} &= \text{GenRad sense} - 20 \log 200 - 3.2 \text{ dB} \\ &= 111 \text{ dB re 1 Volt}/\mu\text{bar} \end{aligned} \tag{4.1}$$

This compares favorably to the sensitivity listed on the specification sheet of -113 dB re 1 Volt/ $\mu$ bar. Figure 4.5 depicts the difference in level between the outputs of the ENDEVCO and the GenRad microphones in one third octave frequency bands for preamp settings of X100 for the ENDEVCO and X1 for the GenRad. No statistical data was obtained. Figure 4.6 is a linear comparison of voltage response to

# ITEM RESPONSE TO VIBRATION

VIBRATION IS PARALLEL TO THE FACE OF ITEM;X LATERAL AXIS

ITEM NAME: MICROPHONE  
 MANUFACTURER: ENDEVCO  
 PART NO.: GC1346742-11-031  
 SERNO: BJ66  
 DATA FILE NAME: XBJ66U1A:D701  
 DATA DISC LABEL: C

FREQ	ITEM	SPL/	INPUT	ACCEL	REQ'D	OBS	NO.
(HZ)	VOLTS	XMISS	VOLTS	VOLTS	G LOAD	G LOAD	TRIES
	(uV)	(DB)	(MV)	(MV)	(G's)	(G's)	
20.0	6.4	83.55	299.0	.234	.38	.38	4
25.0	7.9	85.40	227.0	.295	.48	.48	3
31.5	9.5	86.93	155.0	.373	.60	.60	2
40.0	12.5	89.35	98.1	.470	.76	.76	2
50.0	11.0	88.24	98.9	.590	.95	.95	2
63.0	22.0	94.26	167.0	.738	1.20	1.19	3
80.0	25.0	95.37	275.0	.937	1.52	1.52	2
100.0	23.5	94.83	355.0	1.050	1.70	1.70	2
125.0	28.7	96.57	442.0	1.170	1.90	1.89	2
160.0	33.0	97.78	541.0	1.320	2.15	2.14	2
200.0	42.1	99.90	638.0	1.480	2.41	2.39	2
250.0	57.4	102.59	735.0	1.650	2.69	2.67	2
315.0	27.5	96.20	755.0	1.870	3.02	3.03	2
400.0	27.5	96.20	857.0	2.100	3.40	3.40	2
500.0	39.1	99.26	924.0	2.350	3.80	3.80	2
630.0	53.7	102.01	942.0	2.640	4.27	4.27	2
800.0	79.3	105.40	853.0	2.980	4.81	4.82	2
1000.0	94.0	106.87	592.0	3.350	5.38	5.42	2
1250.0	101.0	107.50	87.1	3.320	5.38	5.37	2
1600.0	213.0	113.98	767.0	3.320	5.38	5.37	3
2000.0	28.1	96.39	1451.0	3.300	5.38	5.34	2

OVERALL BAND SPL: 116.8 DB. REF LEVEL 4.26mV @ 140 DB.

## COMMENTS:

SPL/XMISS: READ 'SPL' FOR MEASURED VOLTAGE RESPONSE.

READ 'XMISS' FOR MEASURED TRANSMISSIBILITY.

G LOADS OBTAINED WERE WITHIN 1.0% OF DESIRED VALUES.

ALL VOLTAGES ARE WITHOUT AMPLIFICATION AND INCLUDE

LINE LOSSES TO PREAMP.

TEST CONDUCTED IN ANECHOIC CHAMBER. RADIAL VIBRATIONS.

MICROPHONE WAS UNCAPPED AND ORIENTED AWAY FROM CABLE PORTS

Figure 4.1 Microphone BJ-66 Lateral Response to Shaker Vibration and Shaker Noise

# ITEM RESPONSE TO VIBRATION

TEST ITEM IS NOT VIBRATING, BUT IS EXPOSED TO SHAKER NOISE

ITEM NAME: MICROPHONE  
 MANUFACTURER: ENDEVCO  
 PART NO.: GC1346742-11-031  
 SERNO: BJ66  
 DATA FILE NAME: NBJ66UX9:D701  
 DATA DISC LABEL: C

FREQ (HZ)	ITEM VOLTS (uV)	SPL/ XMISS (DB)	INPUT VOLTS (MV)	ACCEL VOLTS (MV)	REQ'D G LOAD (G's)	OBS G LOAD (G's)	NO. TRIES
20.0	.3	57.10	299.0	.234	.38	.38	1
25.0	.3	57.10	227.0	.298	.48	.48	1
31.5	1.2	69.14	155.0	.366	.60	.59	1
40.0	.9	66.64	98.1	.471	.76	.76	1
50.0	1.2	69.14	98.9	.590	.95	.95	1
63.0	1.2	69.14	167.0	.744	1.20	1.20	1
80.0	2.4	75.16	275.0	.947	1.52	1.53	1
100.0	4.9	81.18	355.0	1.040	1.70	1.68	1
125.0	7.3	84.70	442.0	1.160	1.90	1.88	1
160.0	8.5	86.04	541.0	1.310	2.15	2.12	1
200.0	18.6	92.80	638.0	1.470	2.41	2.38	1
250.0	50.4	101.46	735.0	1.640	2.69	2.65	1
315.0	69.9	104.30	755.0	1.860	3.02	3.01	1
400.0	42.7	100.02	857.0	2.090	3.40	3.38	1
500.0	36.0	98.54	924.0	2.340	3.80	3.79	1
630.0	43.0	100.08	942.0	2.630	4.27	4.25	1
800.0	31.4	97.35	853.0	2.960	4.81	4.79	1
1000.0	28.7	96.57	592.0	3.340	5.38	5.40	1
1250.0	20.4	93.60	87.1	3.240	5.38	5.24	1
1600.0	23.5	94.83	767.0	3.290	5.38	5.32	1
2000.0	42.7	100.02	1451.0	3.300	5.38	5.34	1

OVERALL BAND SPL: 109.8 DB. REF LEVEL 4.26mV @ 140 DB.

## COMMENTS:

SPL/XMISS: READ 'SPL' FOR MEASURED VOLTAGE RESPONSE.

READ 'XMISS' FOR MEASURED TRANSMISSIBILITY.

ALL VOLTAGES ARE WITHOUT AMPLIFICATION AND INCLUDE  
 LINE LOSSES TO PREAMP.

TEST CONDUCTED IN ANECHOIC CHAMBER. RADIAL VIBRATIONS.  
 MICROPHONE UNCAPPED AND ORIENTED AWAY FROM CABLE PORTS.  
 VOLTAGE LEVELS CORRESPOND TO THOSE FROM FILE 'XBJ66U1A'

Figure 4.2 Microphone BJ-66  
 Response to Shaker Table Noise Only

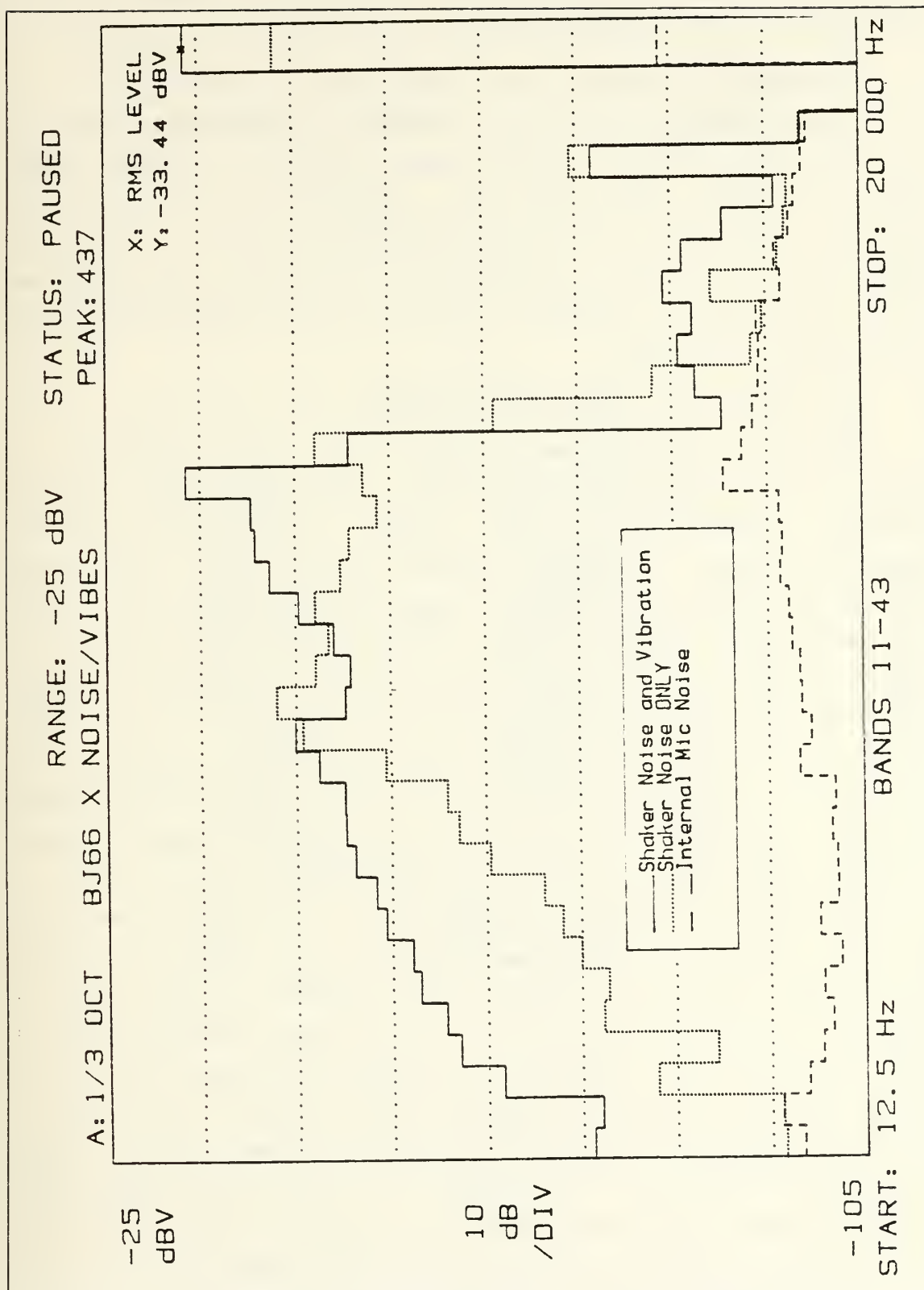


Figure 4.3 BJ-66 Lateral Third Octave  
Vibration/Noise Response



broadband noise between 25 and 2500 Hertz. A trace of the source was shown in Figure 3.7.

#### C. COMPARISON OF ENDEVCO BJ-56 AND BD-37 TO BJ-66

A comparison of the three ENDEVCO microphones response to identical acoustic signal showed each had nearly identical response. The test was conducted in the anechoic chamber using the same 25 to 2500 Hertz source. Figure 4.7 shows the output of each microphone and the internal noise level for BJ-66. Internal noise for each microphone was also nearly identical.

#### D. FREE DECAY AND STATIC DEFLECTION

Axial and radial test results were used to determine values of the damping coefficient, and damped and natural resonant frequencies of the isolator constructed with the bungee material. Separate damping ratios were determined for the positive and negative peaks of the amplitude traces and an average taken. Static tests of a single strand of bungee material was used to determine the material's Young's modulus. Table VI is a summary of the results.

Figure 4.8 and 4.9 shows the frequency spectrum and amplitude trace for a radial free decay test of the bungee material. Figures 4.15 and 4.14 are plots of static spring constant test data. The bungee material was selected to isolate the microphone because it was linear over the expected range of displacement and it was easy to handle. The bungee material's tension was easier to set and the material was easier to control. The bungee material did not absorb epoxy resin and when it came into contact with the epoxy resin it could be peeled away without affecting its elastic properties. No difference was noted in free decay properties between 5 °C and 60 °C. Base ten logarithmic plots of amplitude ratios versus period for axial and radial free decay are shown in figures 4.10, through 4.13.



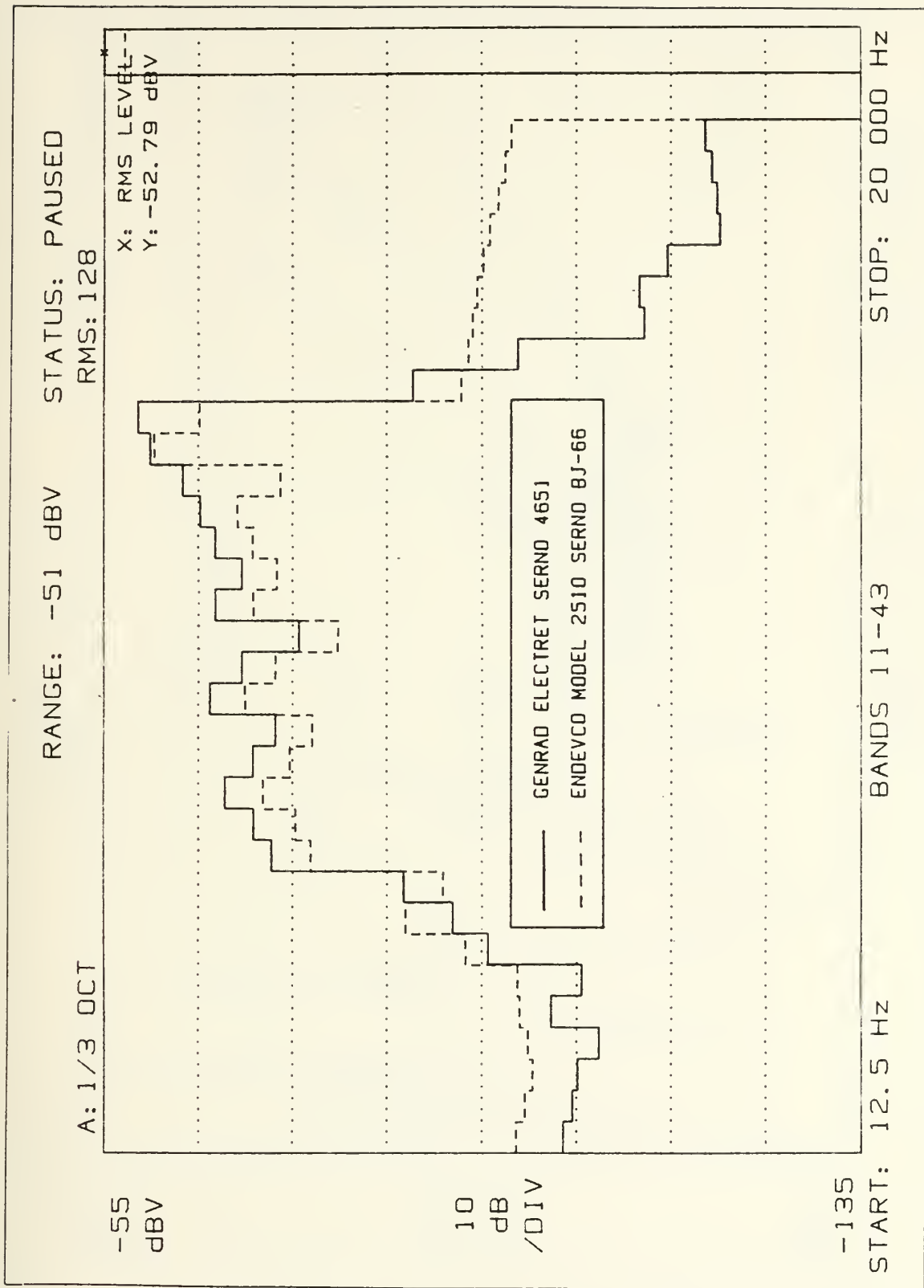


Figure 4.4 Third Octave Voltage Response of BJ-66 and Electret to an Identical Signal

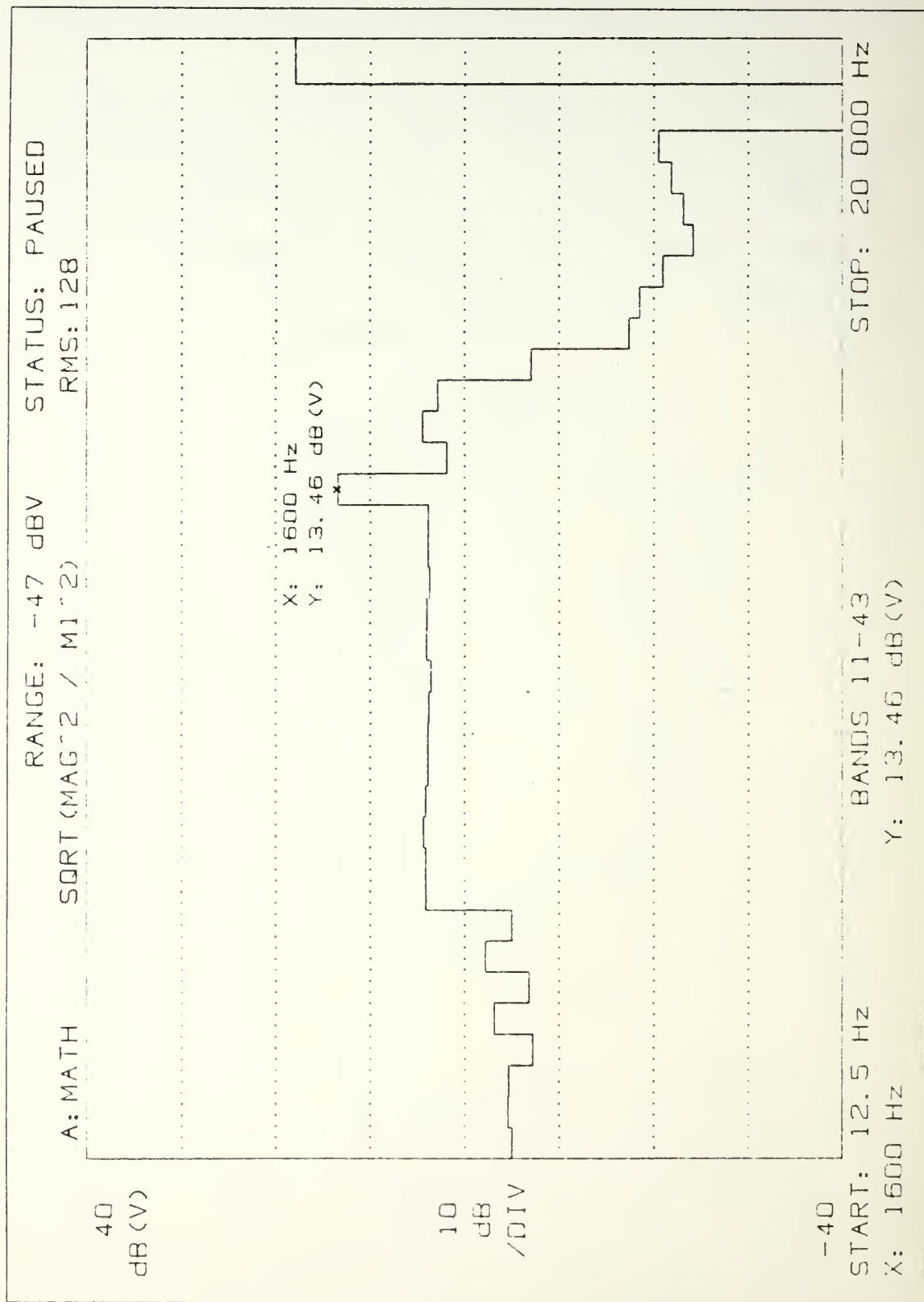


Figure 4.5 DB Level Difference (Electret - BJ-66)

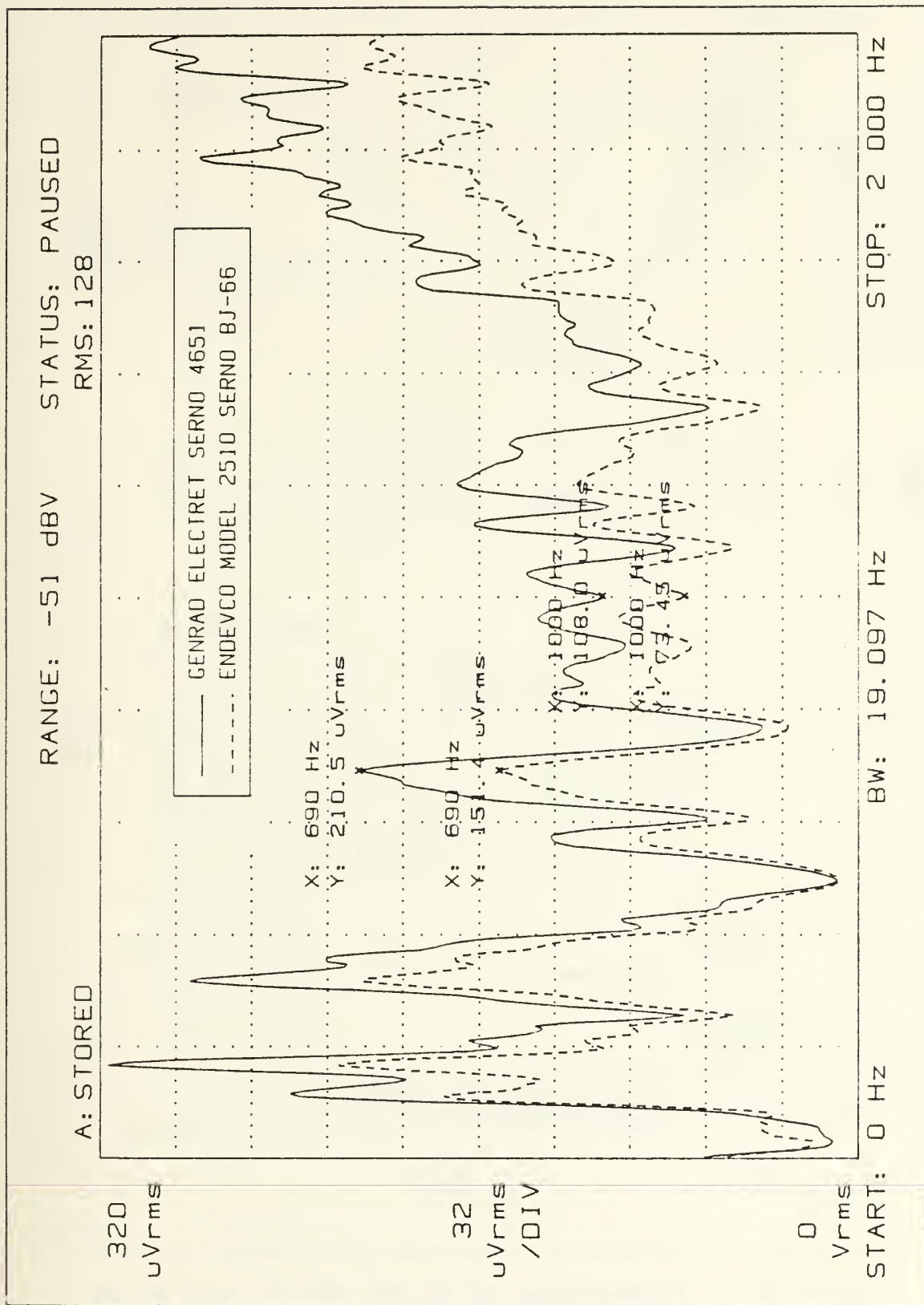


Figure 4.6 Linear Voltage Response for BJ-66 and Electret

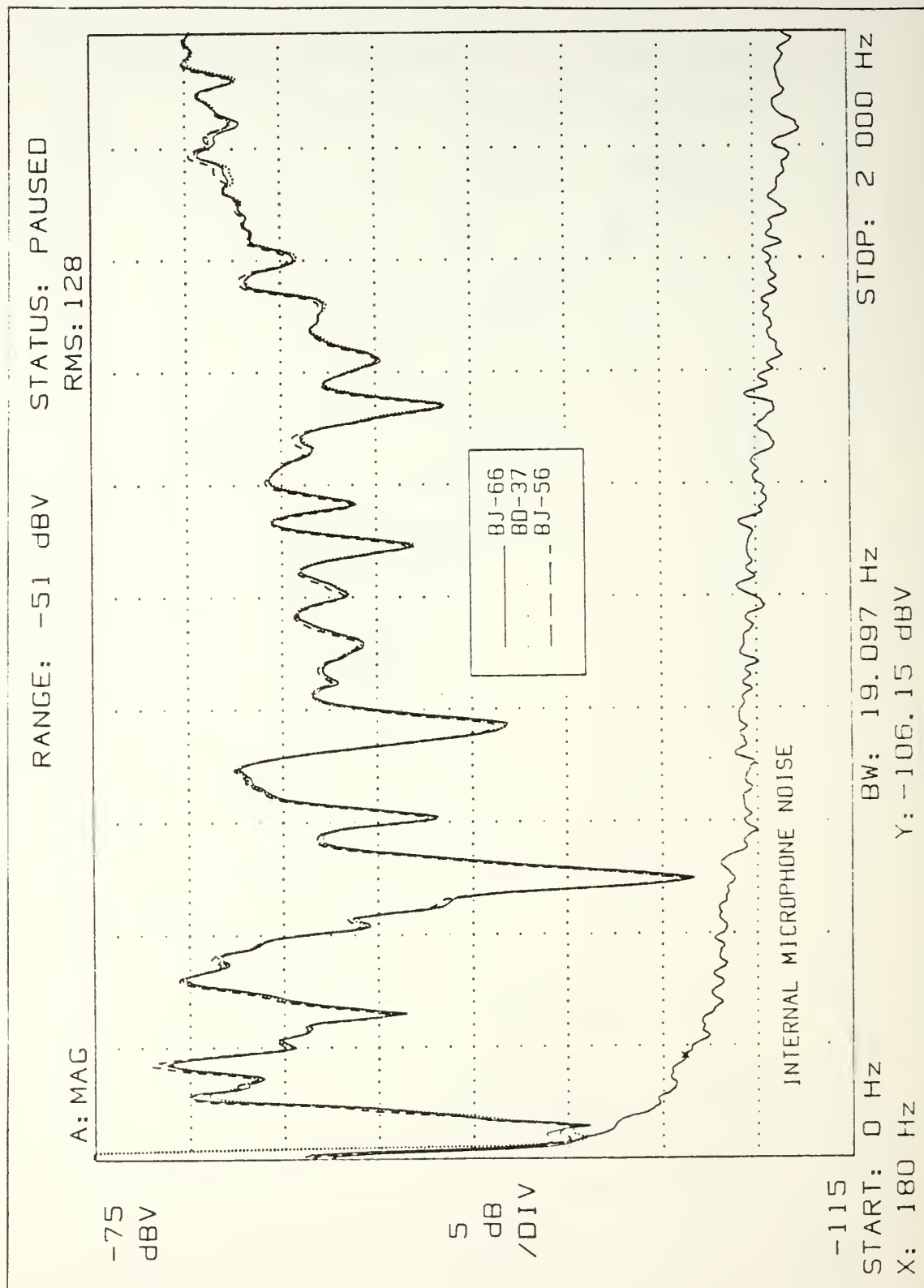


Figure 4.7 Comparisons of BJ-66, BD-37, and BJ-56 Voltage Response

TABLE VI  
FREE DECAY AND STATIC DEFLECTION RESULTS

	Static Deflection		Free Decay	
	Axial	Radial	Axial	Radial
Stiffness (N x 10/m)	.156	.129	NA	NA
Damping Ratio	NA	NA	.043	
Resonant Freq. (Hz)	10	9	11	14
Young's modulus : 20 x 10 <sup>5</sup> Pascal				

The cotton covered elastic thread's stiffness was non-linear. The outer covering of cotton absorbed epoxy and capillary action transmitted epoxy past the point of contact.

#### E. TRANSMISSIBILITY

A comparison was made between results of actual transmissibility tests of each bungee material isolation system and the transmissibility predicted from the damping ratio and the loss tangent. The predicted and actual transmissibility were nearly identical from -3 dB at 20 Hertz to -32 dB at 100 Hertz. The microphone's inherent vibration insensitivity, plus the low transmissibility of the isolation system will allow the microphone to respond satisfactorily to air-borne acoustic vibrations at, or above 20 Hertz. Figures 4.16 and 4.17 are the transmissibility curves for the bungee material. Curves for the predicted viscous and complex modulus transmissibilities were obtained using equations 2.25 and 2.26 respectively.

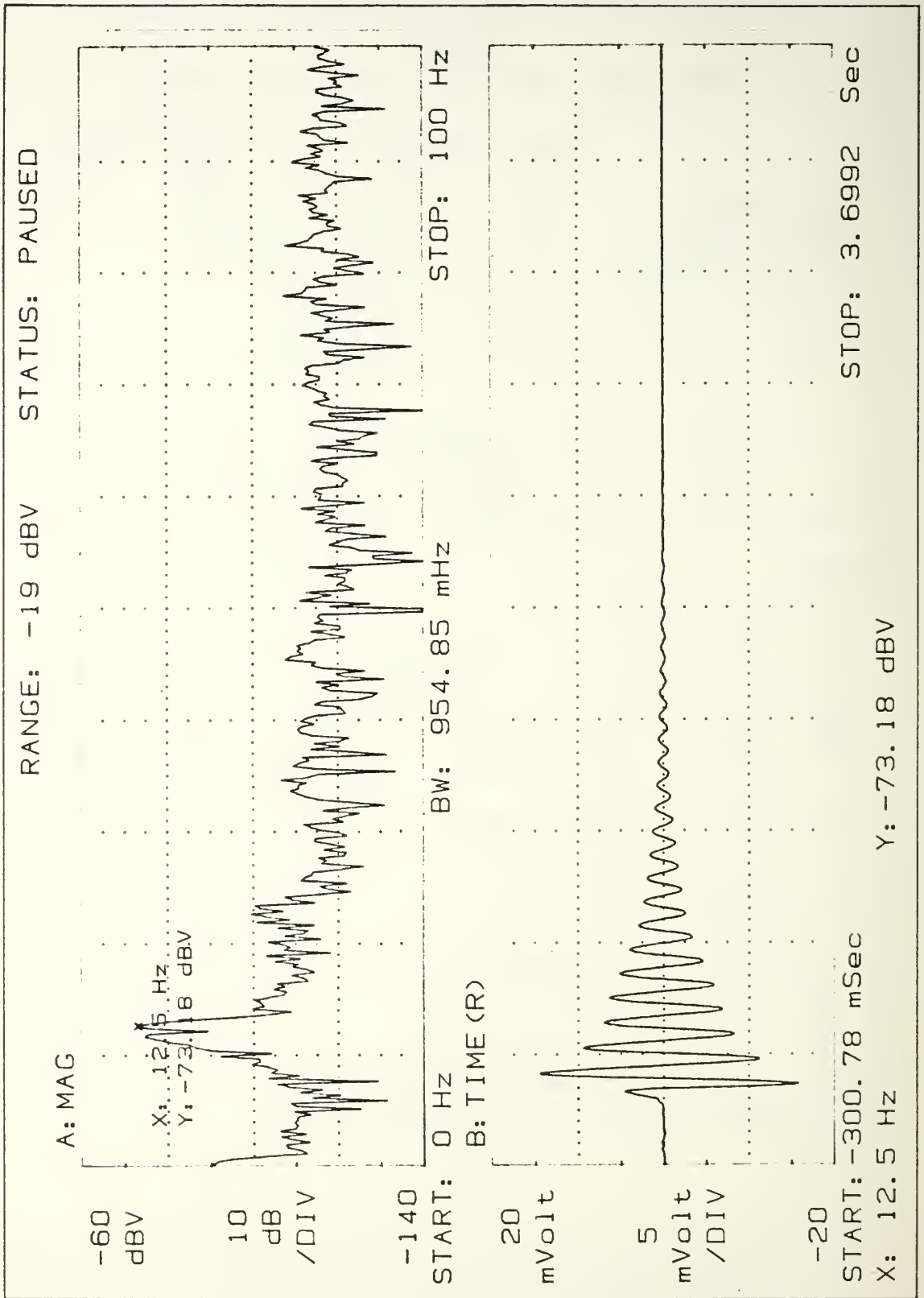


Figure 4.8 Bungee Suspension Radial Free Decay Trace



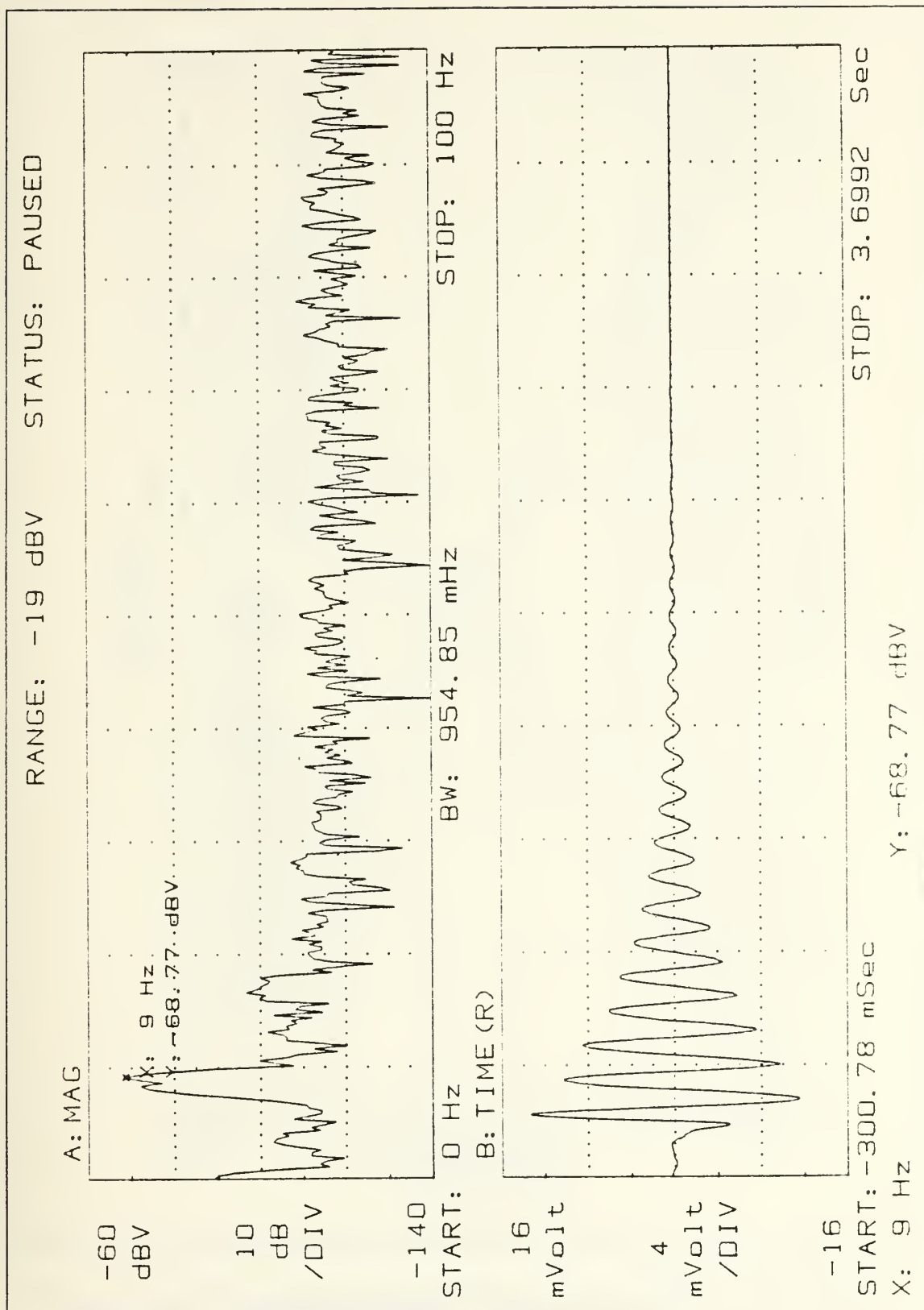


Figure 4.9 Bungee Suspension Axial Free Decay Trace

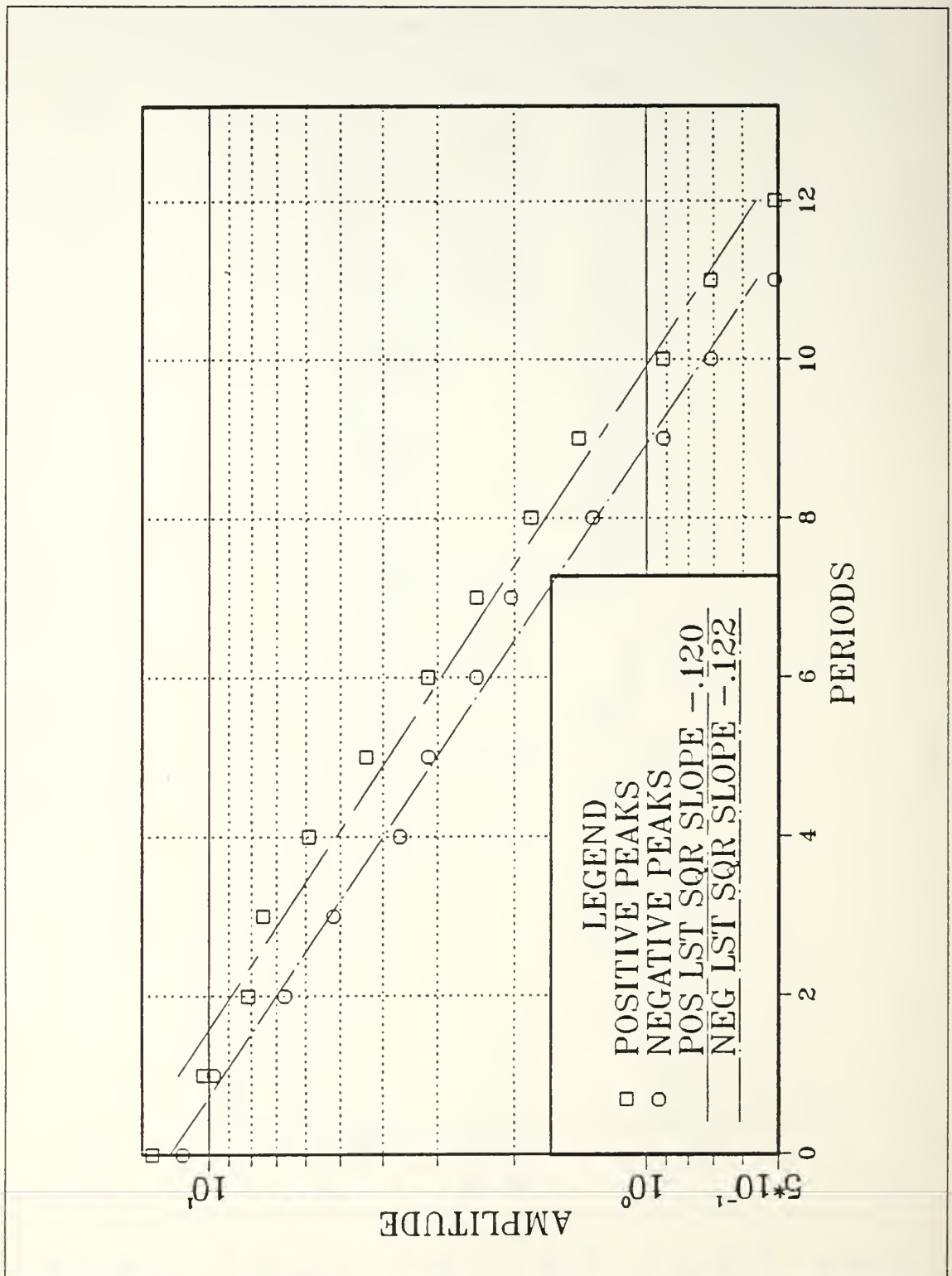


Figure 4.10 Bungee Suspension Axial Amplitude Ratios

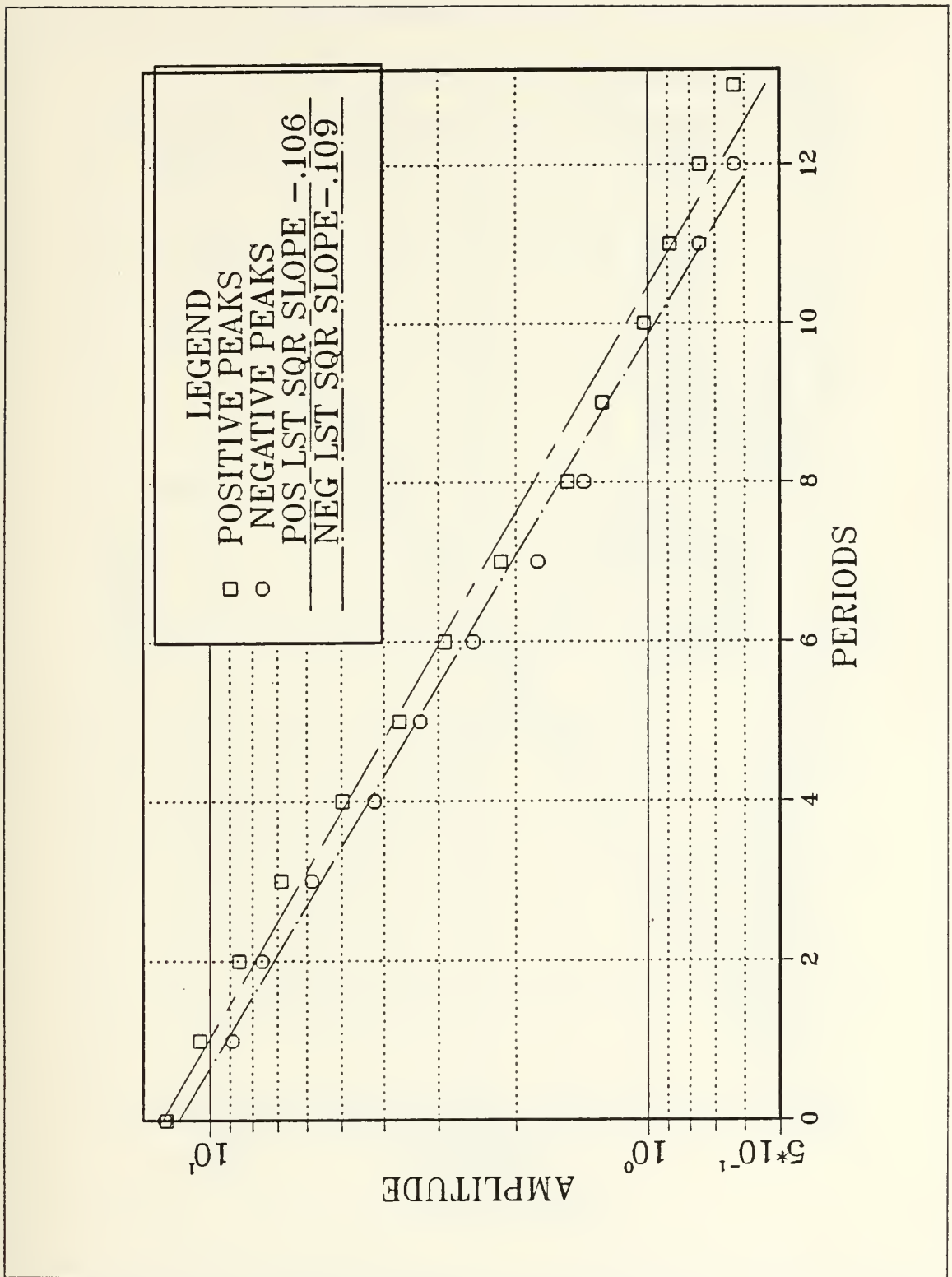


Figure 4.11 Bungee Suspension Axial Amplitude Ratios

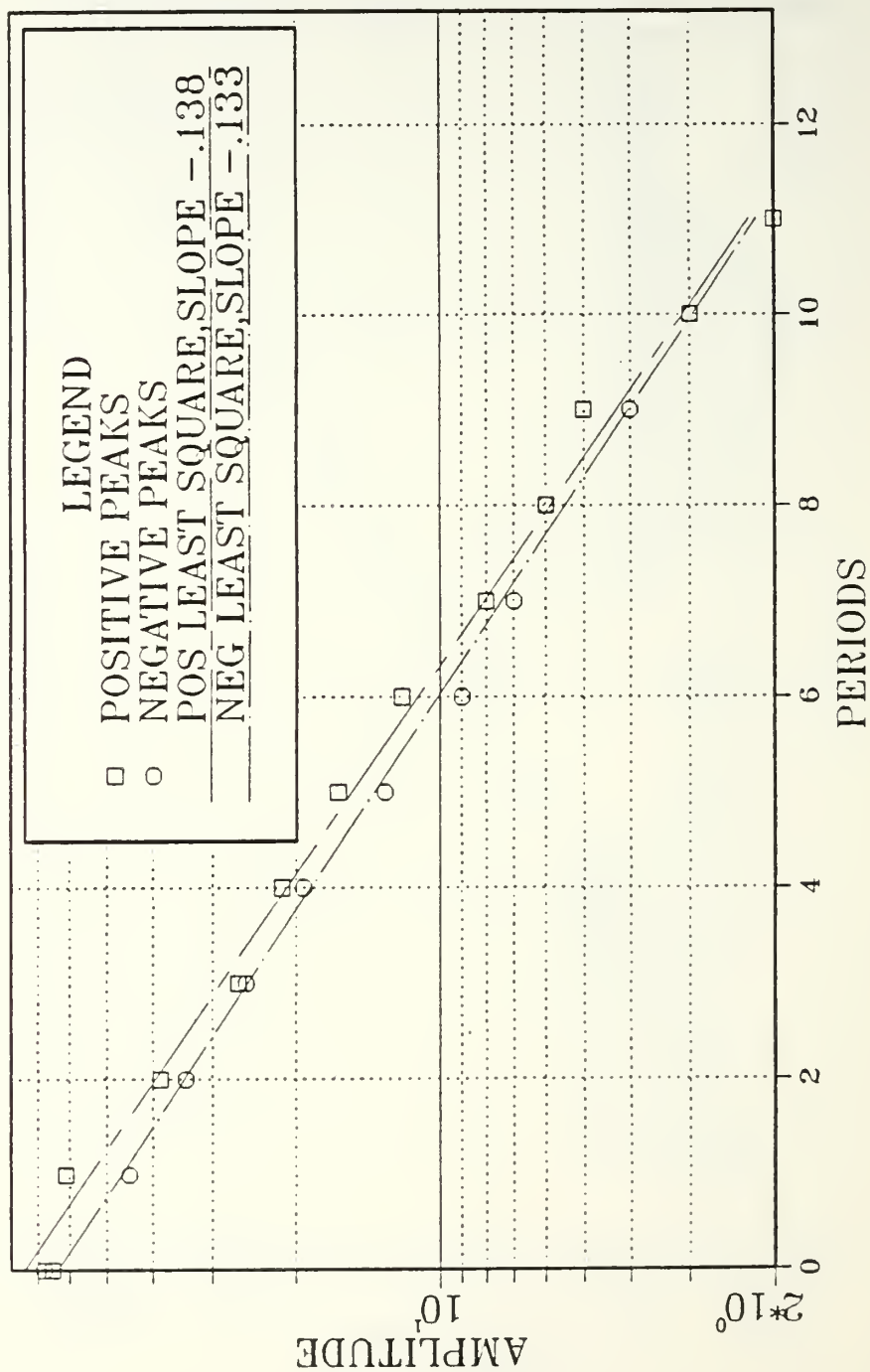


Figure 4.12 Bungee Suspension Axial Amplitude Ratios

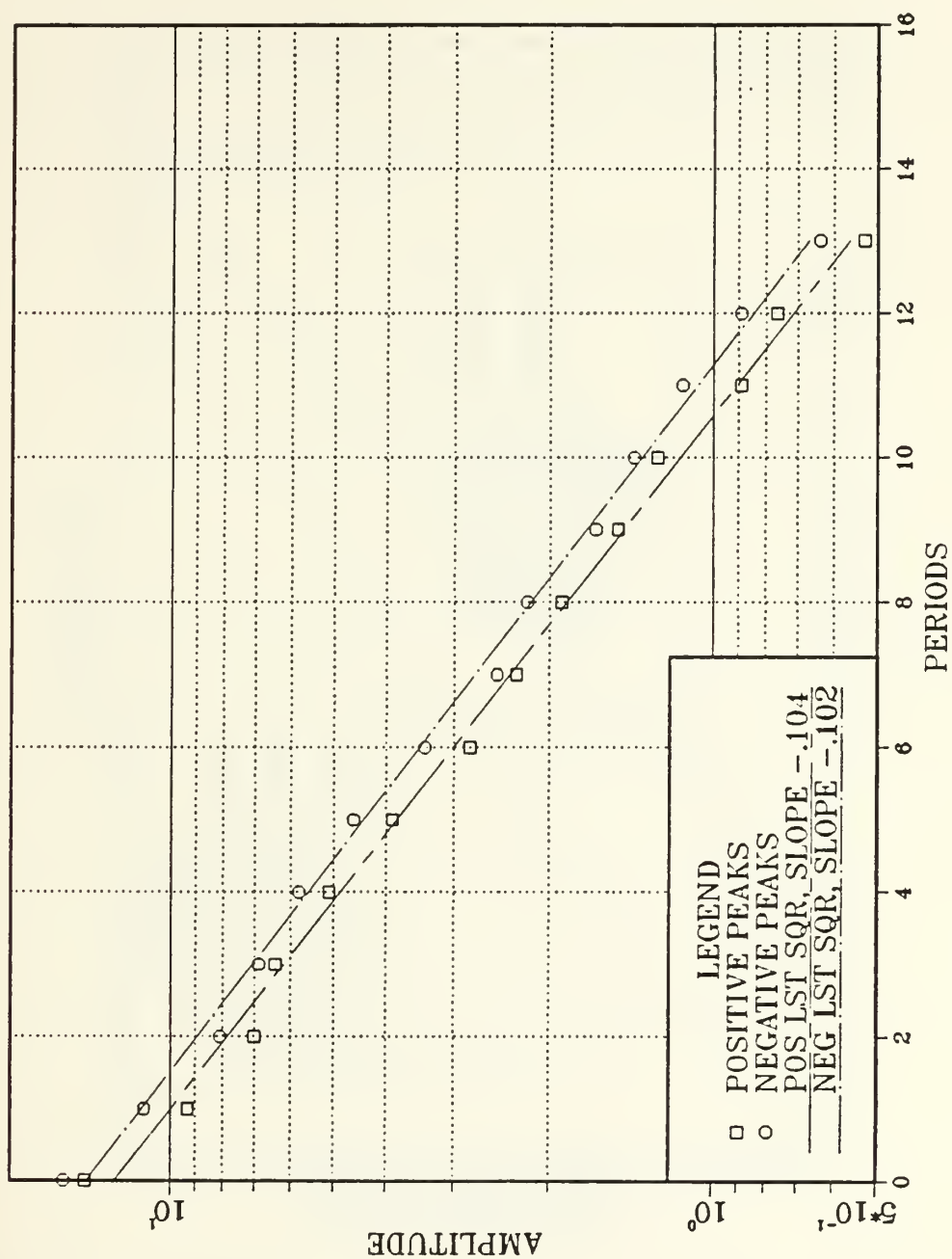


Figure 4.13 Bungee Suspension Radial Amplitude Ratios



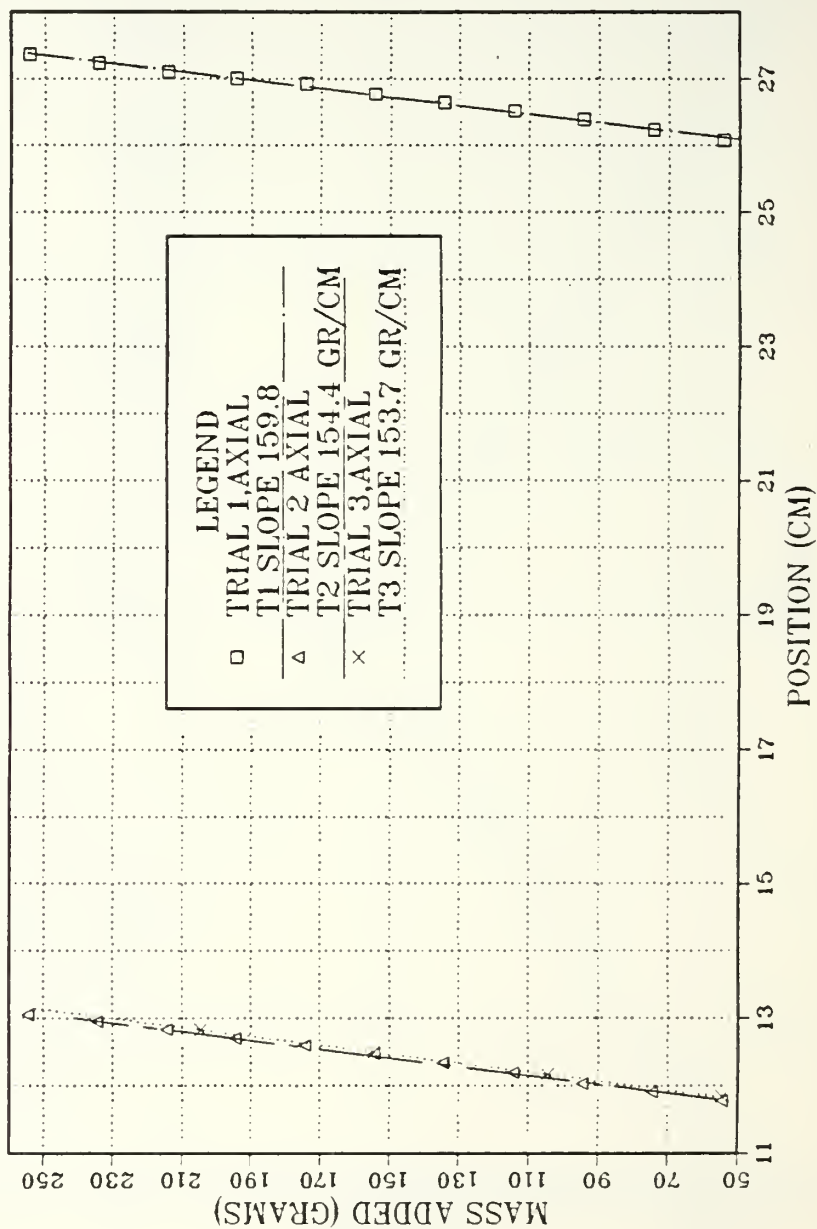


Figure 4.14 Bungee suspension Axial Displacement vs Mass Added

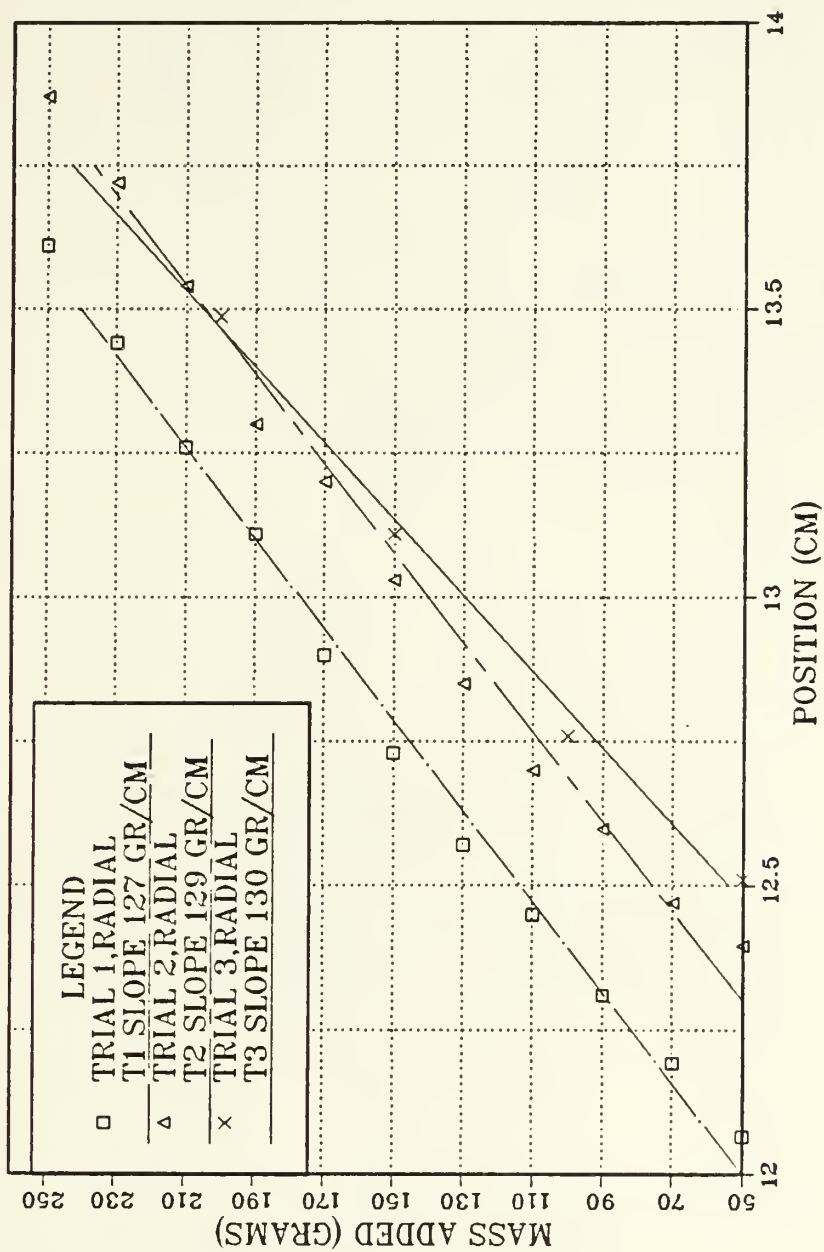


Figure 4.15 Bungee suspension Radial Displacement vs Mass Added

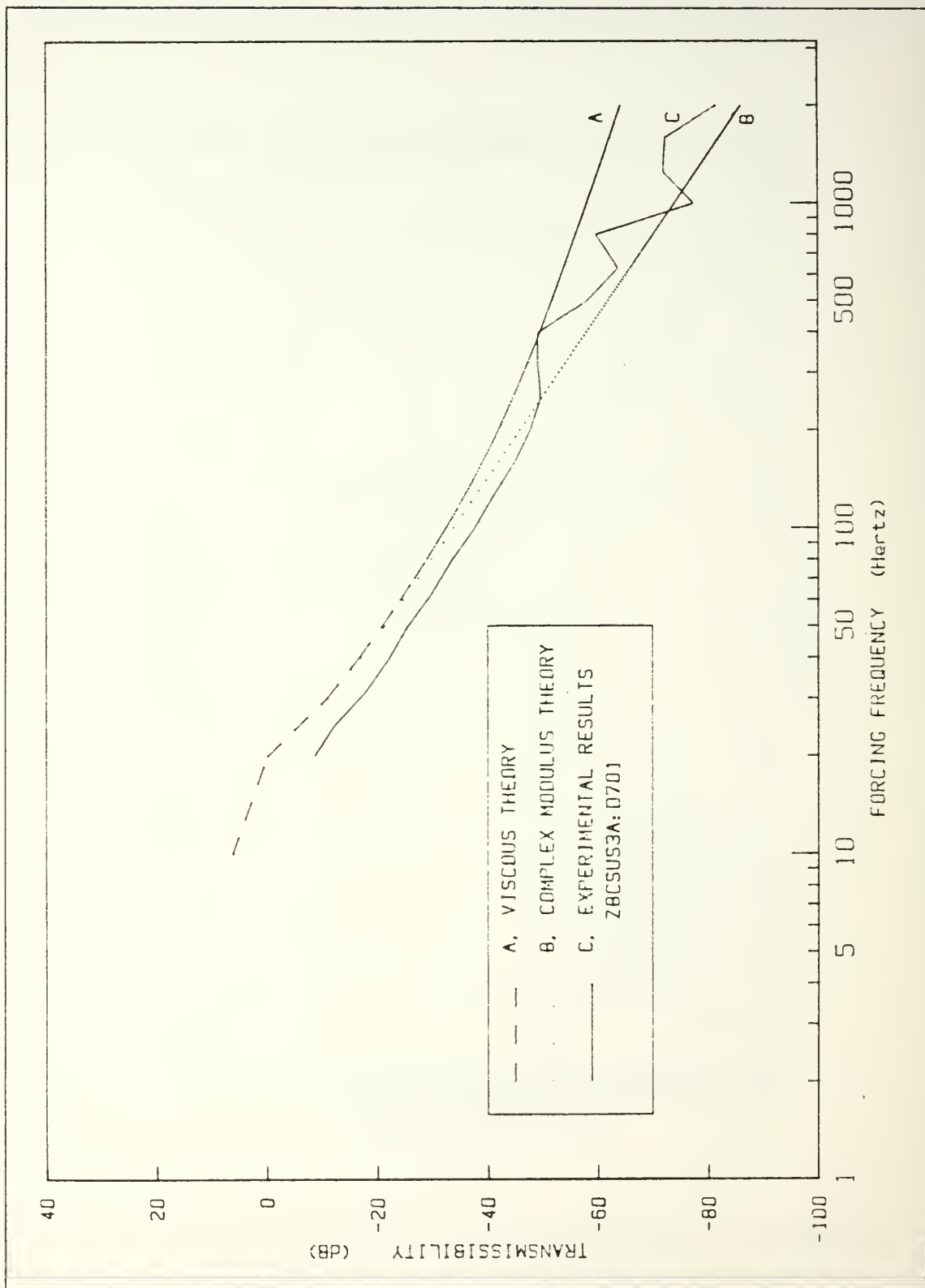


Figure 4.16 Axial Transmissibility for Bungee Isolator

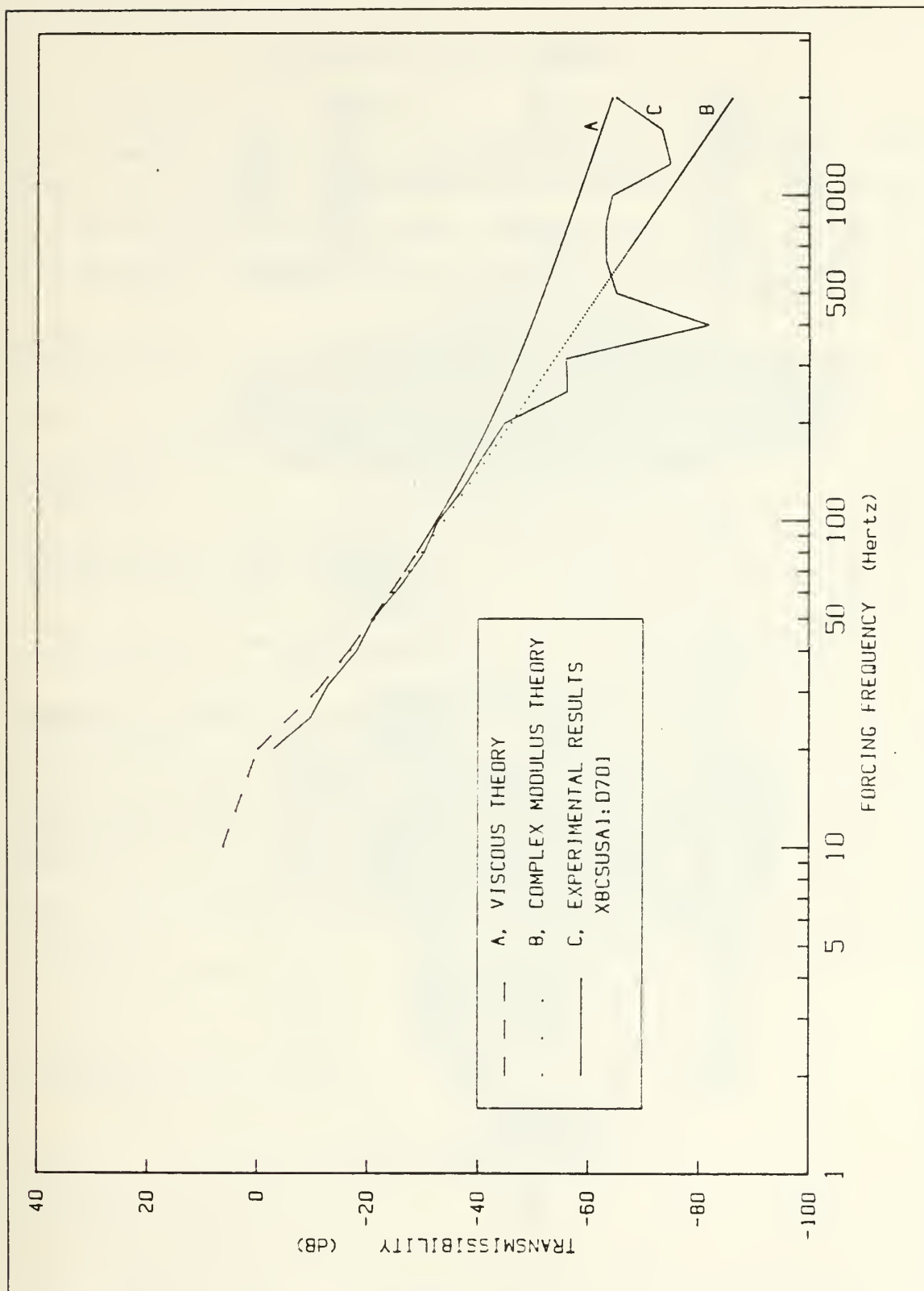


Figure 4.17 Radial Transmissibility for Bungee Isolator

## V. SUMMARY AND CONCLUSIONS

A microphone vibration isolator for the ENDEVCO model 2210 microphone has been designed, built and tested in the laboratory. It provides isolation from expected structural vibrations which should permit ambient noise measurements to be made from about 20 Hz and higher without contamination due to vibration induced signals.

### A. MICROPHONE VIBRATION ISOLATION SYSTEM FOR NASA PROJECT G-313

Figure 5.1 is a drawing of a microphone suspended in one of the three vibration isolation canisters. The suspension material is bungee. It is attached to the microphone and canister by wraps of kite string. The string is coated with Stycast epoxy 1266 (Emeron and Cumming, Canton, MA.) using a 10 gram to 2.8 gram ratio.

### B. RECOMMENDATIONS

A vibration cancelling microphone, with a resonant frequency below 20 Hertz should be produced and procured, and incorporated in a program to regularly monitor payload bay acoustic pressure levels. Alternatively this experiment should be flown regularly on STS flights to record the acoustic pressure amplitudes in the payload bay under various configurations.

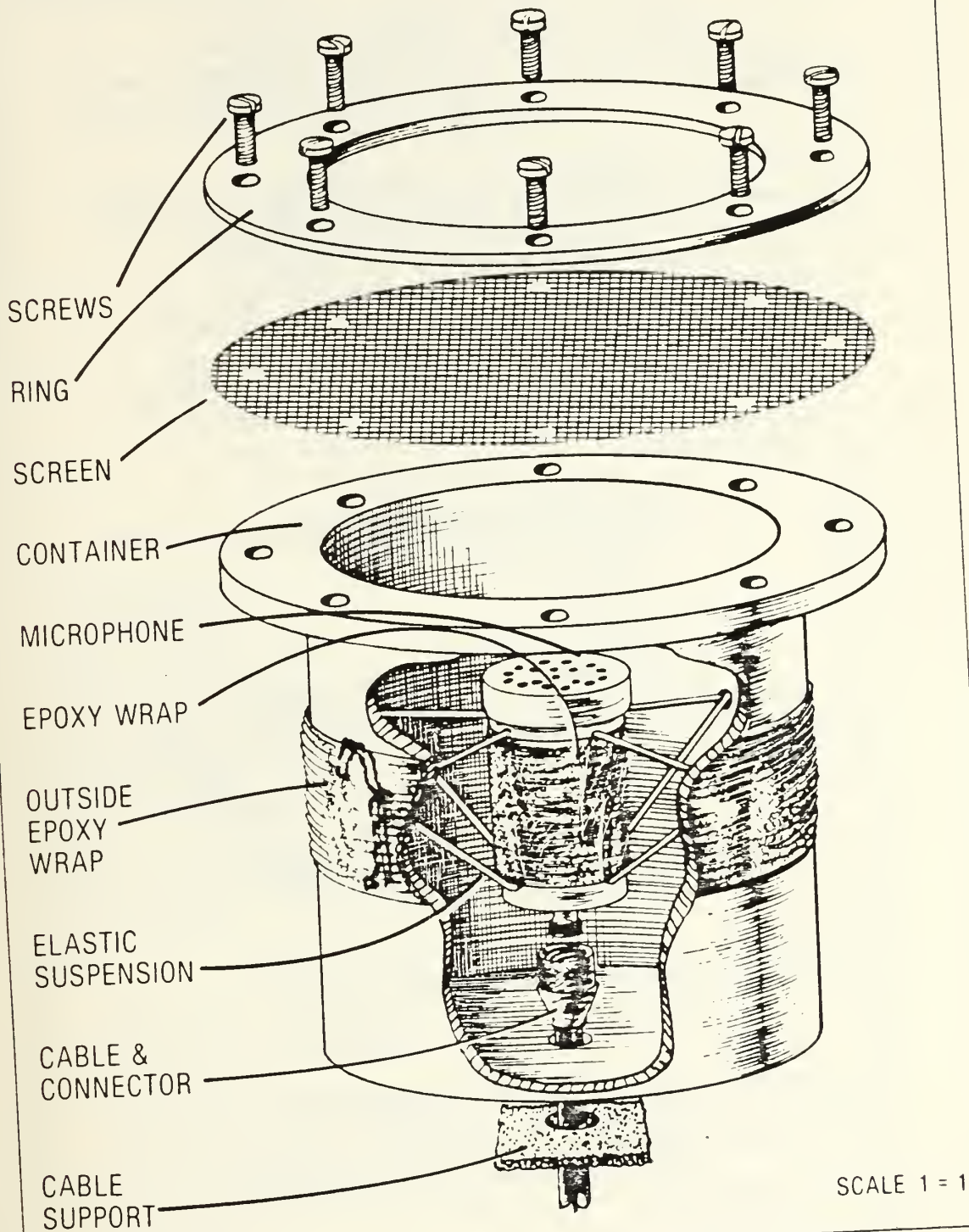


Figure 5.1 Microphone Suspended in Isolating Canister



## APPENDIX A

### SHAKER TABLE CONTROL PROGRAM

```
1 ! *****
2 ! *****
3 !           SHAKER CONTROL
4 !
5 ! This is a control program for space research project NPS-401. It controls
6 ! a shaker table to produce the g loads for EITHER the one third octave band
7 ! frequencies and g loads contained in the NASA GAS Experimenter's
8 ! Handbook or frequency and g load pairs input by the user.
9 ! The program will obtain a volt/g value at the selected frequency and
10 ! then compute the initial voltage. Linear corrections will be used to
11 ! in NASA's EXPERIMENTER's HANDBOOK. The program will control a function
12 ! generator, shaker table, and FFT. The function generator will produce a
13 ! sinusoid at the selected frequency and at a voltage amplitude necessary
14 ! to produce the desired g load.
15 ! Required equipment:
16 !     a. 2 pre amps with roll off control
17 !     b. computer controlled spectrum analyzer
18 !     c. computer controlled function generator
19 !     d. computer terminal
20 !     e. disk drive
21 !     f. printer
22 !     g. shaker table with amp
23 !     h. impedance matching connections as required
24 ! The acceleration will be measured on a previously calibrated
25 ! accelerometer: ENDEVCO ACCELEROMETER 2225M2, SERVO FD95. G load response
26 ! will be measured with the axis of vibration oriented with respect to the
27 ! article under test. Orientation of vibration axis will be as follows:
28 !
29 !     a. parallel to the longitudinal axis of the base
30 !     b. parallel to the lateral axis of the base
31 !     c. perpendicular to the plane of the base
32 !
33 ! After data is recorded the sound pressure level is calculated.
34 ! The reference voltage and db level is input interactively.
35 !
36 !
37 !
38 ! When required an identical test article was mounted opposite the
39 ! article under test for balance.
40 ! Required data files:
41 !     a. None. Entries required are in program or are
42 ! input interactively.
43 !
44 ! Program data lines:
45 !     a. Required g loads, G_REQ(M), and FREQ(M) are read
46 ! in interactively in ROUTINE titled 'KEYBOARD'
47 ! or from data line entries in ROUTINE 'PROGRAM DATA'.
```

```

48 ! Created data files: (data files are created by interactive inputs
49 ! and purged before each run.)
50 !      a. L'CODE'RUN#:D701, contains array FREQ(M);G_LOAD1(M)
51 !          the measured g load;G_REQ(M),the required g load;
52 !          and SPL(M), the sound pressure level.
53 !          Used when the axis of vibration is parallel to
54 !          the longitudinal axis of the base plate.
55 !
56 !      b. W'CODE'RUN#:D701, same as LCODE but used when
57 !          the vibrating axis is parallel to the lateral
58 !          or width axis of the base plate.
59 !      c. V'CODE'RUN#:D701, same as LCODE but used when
60 !          the vibrating axis is perpendicular to the base
61 !          plate.
62 !
63 !      d.N'CODE'RUN#:D701, used whenever the test item is
64 !          exposed ONLY to shaker table NOISE;NOT vibrations.
65 !      e.I'CODE'RUN#:D701, used whenever the test item is
66 !          ISOLATED from BOTH noise AND vibrations.
67 !          from BOTH noise and vibration.
68 !
69 ! TITLE : VOLTAGE RESPONSE TO G LOADS (VOLTRES4) INTERACTIVE INPUTS
70 !
71 GOSUB DIMENSION_ARRAYS
72 GOSUB INTRODUCTION
73 GOSUB TEST_EQUIPMENT_PARAMETERS
74 GOSUB TEST_ITEM_DATA
75 GOSUB TEST_CONDITIONS_FILENAME_INPUTS
76 GOSUB CONCATENATE_FILENAME_INPUTS
77 GOSUB SELECT_DATA_ENTRY_METHOD
78 GOSUB PRINT_HEADERS
79 GOSUB CALIBRATE_EQUIPMENT
80 GOSUB TEST_AT_FREQUENCY_G_LOAD_PAIRS
81 GOSUB PRINT_OVERALL_RESULTS
82 GOSUB CLOSE_FILES_AND_NULL_OUTPUTS
83 GOSUB ANOTHER_RUN
84 END
85 !
86 ! *****
87 ! ***** DIMENSION_ARRAYS *****
88 ! *****
89 DIMENSION_ARRAYS:
90 OPTION BASE 1 ! Sets all array subscripts to start at 1 vice 0.
91 DIM G_LOAD1(25),G_LOAD2(25),G_REQ(25),G_PER_VOLT(25),SPL(25)
92 DIM VOLT_A(25),VOLT_B(25),FREQ(25),VOLT_I(25),ITERATIONS(25)
93 DIM A(25),B(25),C(25),D(25)
94 DIM AXIS$(90)
95 DIM COMMENTS1$(60)
96 DIM COMMENTS2$(60)
97 DIM COMMENTS3$(60)
98 DIM NAME$(28)
99 !
100 RETURN

```

```

101 ! *****
102 ! ***** INTRODUCTION *****
103 ! *****
104 INTRODUCTION:
105 !
106 CLEAR
107 DISP " THIS PROGRAM CONTROLS A FUNCTION GENERATOR THAT INPUTS"
108 DISP " FREQUENCIES AND VOLTAGES TO A SHAKER TABLE TO PRODUCE"
109 DISP " A SPECIFIED G LOAD. THE PROGRAM OUTPUTS THE FOLLOWING:"
110 DISP "      A.*FREQUENCY"
111 DISP "      B.INPUT VOLTAGE AND TEST ITEM* OUTPUT VOLTAGE"
112 DISP "      C.REQUIRED AND OBTAINED* G LOADS"
113 DISP "      D.NUMBER OF ITERATIONS TO ACHIEVE REQUIRED G LOAD*"
114 DISP "      E.EQUIVALENT SOUND PRESSURE LEVEL REF INPUT VALUES*."
115 DISP "      F.OVERALL SOUND PRESSURE LEVEL*"
116 DISP "      G.TRANSMISSIBILITY OF ISOLATION MOUNT*"
117 DISP
118 DISP "ITEMS MARKED WITH * ARE RECORDED ON DATA DISK."
119 DISP
120 DISP " PRESS 'CONT','"
121 WAIT 20000
122 CLEAR
123 DISP "PROGRAM CODES FOR COMPUTER CONTROLLED EQUIPMENT ARE AS "
124 DISP "FOLLOWS:"
125 DISP
126 DISP "      1. PRINTER           : 702 "
127 DISP "      2. FUNCTION GENERATOR : 707 "
128 DISP "      3. SPECTRUM ANALYZER  : 711 "
129 DISP "      4. DATA DISC DRIVE   : 701 "
130 DISP "      5: PLOTTER IS        : 705 "
131 DISP
132 DISP "PRESS CONT"
133 WAIT 10000
134 CLEAR
135 DISP "YOU WILL BE ASKED TO MAKE VARIOUS ENTRIES DURING THE "
136 DISP "INITIALIZATION PHASE. AFTER TYPING IN THE ENTRY PRESS"
137 DISP "THE 'END LINE' KEY. IF A YES RESPONSE IS DESIRED ENTER"
138 DISP " A '1', ENTER A '2' FOR A NO."
139 DISP
140 DISP "PRESS 'CONT','"
141 WAIT 5000
142 CLEAR

```

```

143 DISP "THE FOLLOWING IS A LIST OF INPUTS NECESSARY FOR PROPER"
144 DISP "PROGRAM OPERATION: "
145 !
146 DISP " 1.MAX VOLTAGE FROM FUNCTION GEN TO SHAKER TABLE IN "
147 DISP " MILLIVOLTS:V_MAX."
148 DISP " 2.PRE AMP GAIN VALUES "
149 DISP " 3.ACCELEROMETER G SENSITIVITY IN G's per VOLT."
150 DISP " 4.DESIRED TOLERANCE FROM G REQUIRED."
151 DISP " 5.TEST ITEM NOMENCLATURE"
152 DISP " 6.TEST ITEM MANUFACTURER"
153 DISP " 7.TEST ITEM SENSITIVITY AT SPECIFIED DB LEVEL IN mV"
154 DISP " 8.DESIRED TEST FREQUENCY GLOAD PAIRS IN HZ AND RMS G's."
155 DISP " 9.INITIAL VOLTAGE IN mV."
156 DISP " 10.SENSITIVITY OF ACCELEROMETERS IN mV/G FOR TRANSMISSIBILITY."
157 DISP
158 DISP "PRESS 'CONT'."
159 PAUSE
160 CLEAR
161 !
162 RETURN
163 !
164 ! *****
165 ! ***** TEST_EQUIPMENT_PARAMETERS *****
166 ! *****
167 TEST_EQUIPMENT_PARAMETERS:
168 ROUTINE=1
169 DISP "ENTER THE DAY, MONTH, AND YEAR; IE 24 JULY 84"
170 INPUT TODAY$
171 !
172 CLEAR
173 DISP "ENTER DATA DISC NAME (A,B,C ETC.)"
174 INPUT DATA_DISC$
175 !
176 CLEAR
177 !
178 DISP "ENTER MAX VOLTAGE FROM FUNCTION GENERATOR TO SHAKER TABLE IN"
179 DISP "MILLIVOLTS. MAX VOLTAGE SHOULD NOT EXCEED 3000mV."
180 INPUT V_MAX
181 !
182 CLEAR

```

```

183 DISP "ENTER MAX NUMBER OF TRIES TO ACHIEVE REQUIRED G LOAD BEFORE"
184 DISP "MOVING ON TO THE NEXT FREQ/G_LOAD PAIR. THE FIRST 5 ATTEMPTS"
185 DISP "USE A LINEAR ALGORITHM, ATTEMPTS 6 AND UP USE A CUBIC."
186 DISP "IF USE OF CUBIC IS REQUIRED USUALLY SOMETHING IS WRONG"
187 DISP "WITH THE EQUIPMENT OR THE WAY THE ITEM IS ATTACHED TO "
188 DISP "THE SHAKER TABLE. 10 IS RECOMMENDED."
189 INPUT MAX_TRIES
190 CLEAR
191 DISP "ENTER THE START VOLTAGE IN mV TO BE USED AT START OF "
192 DISP "FREQUENCY G_LOAD PAIR."
193 INPUT INITIAL_VOLTAGE
194 CLEAR
195 !
196 DISP "ENTER PREAMP GAIN FOR THE ACCELEROMETER OR FFT INPUT A ."
197 INPUT GAIN_A
198 !
199 DISP "ENTER PREAMP GAIN FOR THE TEST ITEM OR FFT INPUT B "
200 DISP " EXAMPLE: IF 20 DB ENTER 10, IF 40 DB ENTER 100"
201 INPUT GAIN_B
202 !
203 CLEAR
204 !
205 DISP "ENTER ACCELERATION SENSITIVITY FOR ACCELEROMETER IN G's PER VOLT."
206 INPUT ACCEL_SENSE
207 !
208 !
209 !
210 CLEAR
211 !
212 DISP "ENTER TOLERANCE BETWEEN DESIRED AND OBTAINED G LOADS (RMS G)"
213 DISP "I.E., FOR 5% ENTER 5"
214 INPUT T
215 CLEAR
216 DISP "ENTER A COMMENT LESS THAN 60 CHARACTERS IF DESIRED. IF YOU"
217 DISP "HAVE NO COMMENTS ENTER DOUBLE QUOTE MARKS. THEN PRESS "
218 DISP "'END LINE'."
219 DISP "***** COMMENT LENGTH *****"
220 INPUT COMMENTS1$
221 CLEAR
222 DISP "ENTER ANOTHER COMMENT LESS THAN 60 CHARACTERS IF DESIRED. IF YOU"
223 DISP "HAVE NO COMMENTS ENTER DOUBLE QUOTE MARKS. THEN PRESS "
224 DISP "***** COMMENT LENGTH *****"
225 DISP "'END LINE'."
226 INPUT COMMENTS2$
227 CLEAR
228 GOSUB DISPLAY_EQUIPMENT_PARAMETERS
229 GOSUB CHANGE_INPUTS
230 CLEAR

```



```

231 ! *****
232 ! ***** DISPLAY_EQUIPMENT *****
233 ! *****
234 !
235 DISPLAY_EQUIPMENT_PARAMETERS:
236 DISP "DATE.....";TODAY$
237 DISP "PREAMP GAIN FOR CHANNEL A ....";GAIN_A
238 DISP "ACCELEROMETER SENSITIVITY.....";ACCEL_SENSE;"G PER VOLT"
239 DISP "PREAMP GAIN FOR CHANNEL B IS..";GAIN_B
240 DISP "DATA DISC LABEL.....";;DATA_DISC$
241 DISP "INITIAL VOLTAGE.....";INITIAL_VOLTAGE
242 DISP
243 DISP "COMMENTS"
244 DISP COMMENTS1$
245 DISP COMMENTS2$
246 !
247 RETURN
248 ! *****
249 ! *****TEST_ITEM_DATA,ROUTINE 2*****
250 ! *****
251 !
252 TEST_ITEM_DATA:
253 ROUTINE=2
254 DISP " ENTER TEST ITEM NOMENCLATURE."
255 INPUT NAME$
256 CLEAR
257 !
258 DISP "ENTER MANUFACTURER'S NAME:"
259 INPUT MAN$
260 CLEAR
261 DISP "ENTER PART NUMBER:"
262 INPUT PN$
263 CLEAR
264 DISP "ENTER SERIAL NO:"
265 INPUT SERNO$
266 CLEAR
267 DISP "IF YOU WANT SOUND PRESSURE LEVELS OF THE TEST ITEM"
268 DISP "BASED ON A VOLTAGE SENSITIVITY AND DB REFERENCE LEVEL"
269 DISP "FOR THE TEST ITEM,USED FOR MIKE RESPONSE, ENTER '1'."
270 DISP
271 DISP "IF YOU WANT TO COMPUTE THE VIBRATION TRANSMISSIBILITY IN DB"
272 DISP "FOR AN ISOLATION MOUNT BY MEASURING THE OUTPUT OF BOTH AN"
273 DISP "ACCELEROMETER ISOLATED FROM VIBRATION AND AN ACCELEROMETER"
274 DISP "THAT IS NOT ISOLATED ENTER '2'."
275 INPUT SPL_TRANSMISSIBILITY
276 ON SPL_TRANSMISSIBILITY GOTO 281,291
277 DISP "ENTER VOLTAGE SENSITIVITY IN MILLIVOLTS PER DB REFERENCE LEVEL "
278 DISP "FOR TEST ITEM AND LEAD TO PRE AMP. "
279 INPUT TEST_SENSE
280 CLEAR

```

```

281 DISP "ENTER THE MAX DECIBEL REFERENCE LEVEL IN DB's ."
282 INPUT DB_REF_LEVEL
283 VPG_VIBE=1/ACCEL_SENSE*1000 ! mVolts/G
284 VPG_ISOL=0
285 GOTO 300
286 CLEAR
287 DISP "ENTER SENSITIVITY OF UNISOLATED VIBRATING ACCELEROMETER IN mV/g"
288 INPUT VPG_VIBE
289 DISP
290 DISP "ENTER SENSITIVITY OF VIBRATION ISOLATED ACCELEROMETER IN mV/g."
291 INPUT VPG_ISOL
292 CLEAR
293 DB_REF_LEVEL=0
294 TEST_SENSE=0
295 GOSUB DISPLAY_TEST_ITEM_DATA
296 GOSUB CHANGE_INPUTS
297 CLEAR
298 !
299 RETURN
300 ! *****
301 ! ***** DISP_TEST_ITEM *****
302 ! *****
303 !
304 DISPLAY_TEST_ITEM_DATA:
305 DISP "ITEM NAME:...";NAME$
306 DISP "MANUFACTURER:";MAN$
307 DISP "PART NO.....";PN$
308 DISP "SERNO:.....";SERNO$
309 DISP "VIBE ACCELEROMETER SENSITIVITY:";VPG_VIBE;"mV/G"
310 DISP "ISOL ACCELEROMETER SENSITIVITY:";VPG_ISOL;"mV/G"
311 DISP "TEST ITEM SENSITIVITY:";TEST_SENSE;"MILLIVOLTS @ DB REF LEVEL"
312 DISP "TEST ITEM DB REFERENCE LEVEL:";DB_REF_LEVEL
313 !
314 RETURN
315 ! *****
316 ! ***** ROUT_#3_TEST_COND_FILENAME_INPUT *****
317 ! *****
318 TEST_CONDITIONS_FILENAME_INPUTS:
319 ROUTINE=3
320 DISP "ENTER '1' IF VIBRATING AXIS IS PERPENDICULAR TO THE FACE OF "
321 DISP " THE TEST ITEM OR AXIALLY (Z LONGITUDINAL AXIS). "
322 DISP "ENTER '2' IF VIBRATING AXIS IS PARALLEL TO THE FACE OF THE "
323 DISP " TEST ITEM RADially (X LATERAL DIRECTION). "
324 DISP "ENTER '3' IF VIBRATING AXIS IS PARALLEL TO THE FACE OF THE "
325 DISP " TEST ITEM RADially (Y LATERAL DIRECTION). "
326 DISP "ENTER '4' IF TEST ITEM IS NOT VIBRATING BUT IS EXPOSED TO "
327 DISP "SHAKER NOISE"
328 DISP
329 DISP "ENTER '5' IF TEST ITEM IS ISOLATED FROM NOISE AND VIBRATION."
330 INPUT AXIS
331 CLEAR

```

```

332 IF AXIS=1 THEN 333 ELSE 337
333   AXIS$="VIBRATION IS PERPINDICULAR TO THE FACE OF ITEM;Z LONG. AXIS."
334   A$="Z" ! Assigns 'L' as the first letter in the filename.
335   GOTO 363
336 !
337 IF AXIS=2 THEN 338 ELSE 342
338   AXIS$="VIBRATION IS PARALLEL TO THE FACE OF ITEM;X LAT DIRECTION."
339   A$="X" ! Assigns 'W' as the first letter in the filename.
340   GOTO 363
341 !
342 IF AXIS=3 THEN 343 ELSE 347
343   AXIS$="VIBRATION IS PARALLEL TO THE FACE OF ITEM;Y LAT DIRECTION."
344   A$="Y" ! Assigns 'N' as the first letter in the filename.
345   GOTO 363
346 !
347 IF AXIS=4 THEN 348 ELSE 353
348   AXIS$="TEST ITEM IS NOT VIBRATING, BUT IS EXPOSED TO SHAKER NOISE"
349   A$="N" ! Assigns letter 'N' as first letter in file name
350   AXIS$="TEST ITEM IS NOT VIBRATING, BUT IS EXPOSED TO SHAKER NOISE"
351   GOTO 357
352 !
353 IF AXIS=5 THEN 354
354   AXIS$="TEST ITEM IS ISOLATED FROM SHAKER NOISE AND VIBRATION"
355   A$="I"
356 CLEAR
357 DISP "ENTER THE RUN NUMBER. IE IF THIS IS THE SECOND RUN FOR THESE "
358 DISP "TEST CONDITIONS ON THIS TEST ITEM THEN ENTER '2'."
359 INPUT RUN_NO$
360 CLEAR
361 !
362 DISP "ENTER AN 8 CHARACTER OR LESS ALPHANUMERIC CODE THAT WILL BE "
363 DISP "USED TO CREATE THE FILENAME. THE CODE SHOULD BE PECULIAR TO "
364 DISP "THIS TEST ITEM. IT SHOULD DESCRIBE CONDITIONS OTHER THAN THE "
365 DISP "ENVIRONMENT OR RUN NUMBER. example BJ56C, BJ56 IS PART OF THE "
366 DISP "SERIAL NUMBER AND 'C' INDICATES THAT THE MIKE WAS CAPPED."
367 DISP
368 DISP
369 DISP "THE SERIAL NUMBER FOR ITEM UNDER TEST IS:";SERNO$
370 INPUT CODE$
371 !
372 D$="D701" ! Disk drive code
373 CLEAR
374 GOSUB DISPLAY_TEST_CONDITIONS
375 GOSUB CHANGE_INPUTS
376 RETURN

```

```

377 ! *****
378 ! ***** _DISPLAY_TEST_COND_ *****
379 ! *****
380 !
381 DISPLAY_TEST_CONDITIONS:
382 FILE$=A$&CODE$&RUN_NO$&D$
383 DISP "CONDITIONS:.....";AXIS$
384 DISP "AXIS CODE:.....";A$
385 DISP "ITEM CODE :.....";CODE$
386 DISP "FILE NAME WILL BE:";FILE$
387 !
388 RETURN
389 ! *****
390 ! ***** CONCATENATE_FILENAME_INPUTS *****
391 ! *****
392 CONCATENATE_FILENAME_INPUTS:
393 ! Concatenate the data file name.
394 !
395 FILE$=A$&CODE$&RUN_NO$&D$
396 !
397 CLEAR
398 DISP "DOES A DATA FILE NAMED ";FILE$;" ALREADY EXIST?"
399 DISP "ENTER 1 IF YES"
400 DISP "ENTER 2 IF NO "
401 INPUT EXIST
402 IF EXIST=1 THEN PURGE FILE$ ELSE 406
403 CREATE FILE$,125,8
404 ASSIGN# 1 TO FILE$
405 RETURN
406 IF EXIST=2 THEN CREATE FILE$,125,8 ELSE 398
407 ASSIGN# 1 TO FILE$
408 CLEAR
409 !
410 RETURN

```

```

411 ! *****
412 ! ***** SELECT_DATA_ENTRY_METHOD *****
413 ! *****
414 SELECT_DATA_ENTRY_METHOD:
415 !
416 DISP "ENTER THE NUMBER (1 or 2) THAT REPRESENTS THE METHOD TO"
417 DISP "BE USED TO SELECT TEST FREQUENCY AND G LOAD PAIRS."
418 DISP
419 DISP "ENTER '1' TO USE THIRD OCTAVE BAND FREQUENCIES: 20 TO 2000 HZ,"
420 DISP "AND 6 LOADS ASSOCIATED WITH FIGURE 1 VIBRATIONS,ACCELERATION"
421 DISP "SPECTRAL DENSITY GRAPH CONTAINED IN THE NASA GET AWAY SPECIAL"
422 DISP "EXPERIMENTER'S HANDBOOK."
423 DISP
424 DISP "ENTER '2' TO INPUT YOUR OWN SELECTED FREQUENCY AND 6 LOAD PAIRS."
425 !
426 INPUT METHOD
427 ON METHOD GOSUB PROGRAM_DATA ,KEYBOARD_ENTRY
428 RETURN
429 PROGRAM_DATA:
430 NF=21
431 RESTORE 434
432 FOR L=1 TO NF
433 READ FREQ(L)
434 DATA 20,25,31.5,40,50,63,80,100,125,160
435 DATA 200,250,315,400,500,630,800,1000,1250,1600,2000
436 !
437 NEXT L
438 !
439 RESTORE 442
440 FOR L=1 TO NF
441 READ G_REQ(L)
442 DATA .38,.48,.6,.76,.95,1.2,1.52,1.7,1.9,2.15
443 DATA 2.41,2.69,3.02,3.4,3.8,4.27,4.81,5.38,5.38,5.38,5.38
444 !
445 NEXT L
446 !
447 CLEAR
448 DISP "THIRD OCTAVE BAND FREQUENCIES AND "
449 DISP "REQUIRED RMS G LOADS ARE AS FOLLOWS:"
450 DISP USING 451 ; "FREQ","G LOAD","FREQ","G LOAD"
451 IMAGE 6X,4A,2X,6A,6X,4A,2X,6A
452 !
453 FOR L=1 TO 10
454 DISP USING 455 ; FREQ(L),G_REQ(L),FREQ(L+10),G_REQ(L+10)
455 IMAGE 5X,4D.D,3X,DD.DD,7X,4D.D,3X,DD.DD
456 NEXT L
457 DISP USING 458 ; FREQ(21),G_REQ(21)
458 IMAGE 26X,4D.D,3X,DD.DD
459 RETURN

```

```

460 ! *****
461 ! ***** KEYBOARD_ENTRY *****
462 ! *****
463 KEYBOARD_ENTRY:
464     ROUTINE=4
465     DISP "ENTER NUMBER OF FREQUENCY,6 LOAD PAIRS TO BE TESTED."
466     DISP "NUMBER OF PAIRS MUST NOT EXCEED 25."
467 !
468     INPUT NF
469     FOR L=1 TO NF
470         DISP "ENTER THE NUMBER";L;"TEST FREQUENCY AND 6 LOAD PAIR."
471         DISP "ENTER FREQUENCY IN HERTZ AND 6 LOAD IN RMS G's."
472         DISP "FOR 200 HZ AND 1.21 (RMS) 6 ENTER: 200,1.21 ."
473         INPUT FREQ(L),G_REQ(L)
474     NEXT L
475 CLEAR
476     GOSUB PERUSE
477 !
478     RETURN
479 PERUSE:
480     DISP "IF YOU WOULD LIKE TO REVIEW"
481     DISP "THE FREQ/6 PAIRS ENTERED "
482     DISP "THEN ENTER '1', IF NOT ENTER '2'."
483     INPUT REVIEW
484     IF REVIEW=1 THEN GOSUB DISPLAY ELSE RETURN
485     RETURN
486 DISPLAY:
487     FOR L=1 TO NF
488         DISP FREQ(L),G_REQ(L)
489     NEXT L
490     GOSUB CHANGE_INPUTS
491     RETURN
492 ! *****
493 ! ***** CHANGE_INPUTS *****
494 ! *****
495 CHANGE_INPUTS:
496     DISP
497     DISP
498     DISP "IF YOU WOULD LIKE TO MODIFY ANY OF THE "
499     DISP "THESE ENTRIES ENTER '1'; IF NOT ENTER '2'."
500     DISP
501     INPUT CHANGES
502     IF CHANGES=1 THEN 503 ELSE RETURN
503     ON ROUTINE GOSUB TEST_EQUIPMENT_PARAMETERS ,TEST_ITEM_DATA ,TEST_CONDITIONS_FILENAME_INPUTS
,KEYBOARD_ENTRY
504 RETURN

```



```

505 ! *****
506 ! ***** PRINT_HEADERS *****
507 ! *****
508 PRINT_HEADERS:
509 PRINTER IS 702
510 PRINT CHR$ (12)
511 PRINT CHR$ (27)&"%k9S"
512 PRINT USING 513 ; TODAY$
513 IMAGE 50X,17A
514 !
515 PRINT
516 PRINT USING 517 ; "ITEM RESPONSE TO VIBRATION"
517 IMAGE 10X,16X,26A
518 PRINT
519 PRINT USING 520 ; AXIS$
520 IMAGE 10X,80A
521 PRINT
522 PRINT USING 523 ; "ITEM NAME: ";NAME$
523 IMAGE 10X,30A,X,27A
524 PRINT USING 523 ; "MANUFACTURER: ";MAN$
525 PRINT USING 523 ; "PART NO. : ";FN$
526 PRINT USING 523 ; "SERNO: ";SERNO$
527 PRINT USING 528 ; "ACCEL PRE AMP GAIN: ";GAIN_A
528 IMAGE 10X,30A,4D.D
529 PRINT USING 528 ; "TEST ITEM PRE AMP GAIN: ";GAIN_B
530 PRINT USING 523 ; "DATA FILE NAME: ";FILE$
531 PRINT USING 523 ; "DATA DISC LABEL: ";DATA_DISC$
532 IMAGE 10X,15A,X,15A
533 PRINT
534 !
535 IMAGE 10X,28A,X,DD,20A
536 PRINT
537 !
538 ! Some abbreviations.
539 !
540 Q$="OBS" ! observed
541 N$="NO."
542 V$="VOLTS"
543 R$="REQ'D"
544 ! Print headings for printed output.
545 PRINT USING 546 ; "FREQ","ITEM","SPL/","INPUT","ACCEL",R$,Q$,N$
546 IMAGE 10X,4A,4X,5A,3X,5A,2X,5A,3X,5A,2X,5A,4X,3A,5X,3A
547 PRINT USING 548 ; V$, "XMISS",V$,V$, "G LOAD", "G LOAD", "TRIES"
548 IMAGE 18X,5A,2X,5A,3X,5A,3X,5A,2X,6A,2X,6A,2X,6A
549 PRINT USING 550 ; "(HZ)", "(uV)", "(DB)", "(MV)", "(MV)", "(G's)", "(G's)"
550 IMAGE 10X,4A,4X,4A,4X,4A,4X,5A,3X,5A,2X,5A,2X,5A
551 !
552 RETURN

```

```

553 ! *****
554 ! ***** CALIBRATE_EQUIP *****
555 ! *****
556 CALIBRATE_EQUIPMENT:
557 DISP "EQUIPMENT IS BEING CALIBRATED AND SET."
558 !
559 ! Set equipment initial parameters.
560 ! 707 addresses the HP3314A Function Generator.
561 ! 711 addresses the HP3582A Spectrum analyzer.
562 ! See appropriate manual for decoding.
563 OUTPUT 711 ;"FRS"
564 OUTPUT 711 ;"IM2AC1BC1A55BS5MD3SP9SC1AV2MP63MN1"
565 OUTPUT 711 ;"AA1AB1NU2"
566 !
567 ! Set function generator
568 OUTPUT 707 ;"CADE1FU1M01LV1SR1SL1"
569 !
570 RETURN
571 ! *****
572 ! ***** TEST_FREQUENCY_G_LOAD_PAIRS *****
573 ! *****
574 TEST_AT_FREQUENCY_G_LOAD_PAIRS:
575 SUM_SPL=0
576 FOR M=1 TO NF
577 !
578 !
579 DISP "TEST FREQUENCY:";FREQ(M)
580 DISP "REQUIRED G LOAD:";G_REQ(M)
581 GOSUB RESET_COUNTERS_ADDERS
582 GOSUB VOLTAGE_LIMIT_CHECK
583 GOSUB OUTPUT_FREQUENCY_AND_VOLTAGE
584 GOSUB TEST_PARAMETERS
585 GOSUB MEASURE_Gs_ADJUST_VOLTAGE
586 GOSUB MEASURE_AND_RECORD_FINAL_VALUES
587 GOSUB PRINT_INDIVIDUAL_RESULTS
588 DISP "NEXT FREQUENCY,G REQUIRED INPUT FOR TEST."
589 !
590 NEXT M
591 RETURN

```

```

592 ! *****
593 ! ***** TEST_PARAMETERS *****
594 ! *****
595 TEST_PARAMETERS:
596   DISP "TEST FREQUENCY:";FREQ(M);"HZ"
597   DISP "REQUIRED G LOAD:";G_REQ(M);"G's"
598 !
599   G_MAX=T/100*G_REQ(M)+G_REQ(M)
600   G_MIN=G_REQ(M)-T/100*G_REQ(M)
601   DISP "G LOAD TOLERANCE IS + OR -";T;"% ; FROM";G_REQ(M);"."
602   DISP "G LOAD RANGE IS FROM";G_MIN;"TO";G_MAX;"."
603   RETURN
604 ! *****
605 ! *****
606 ! ***** VOLTAGE_LIMIT_CHECK *****
607 ! *****
608 !
609 VOLTAGE_LIMIT_CHECK:
610   DISP "CHECKING THAT REQUIRED VOLTAGE DOES NOT EXCEED";V_MAX
611   IF ABS (V)>V_MAX THEN 612 ELSE RETURN
612   DISP "SELECTED INPUT VOLTAGE OF";V;"EXCEEDS SHAKER TABLE "
613   DISP "YOUR PRE SET LIMIT WAS";V_MAX;"MILLIVOLTS."
614   WAIT 5000
615   GOSUB CLOSE_FILES_AND_NULL_OUTPUTS
616   GOSUB ANOTHER_RUN
617   END
618 ! *****
619 ! ***** OUTPUT_FREQ_AND_VOLTAGE *****
620 ! *****
621 OUTPUT_FREQUENCY_AND_VOLTAGE:
622   INITIAL_VOLTAGE=100
623   DISP "RUNNING FUNCTION GENERATOR AND FFT AT THIS TIME."
624   DISP
625   OUTPUT 707 ;"FR",FREQ(M),"HZ"
626   OUTPUT 707 ;"AF",V,"MV"
627 !
628   OUTPUT 711 ;"AA1"
629   OUTPUT 711 ;"AD",FREQ(M),"RE"
630   WAIT 4500
631 !
632   OUTPUT 711 ;"LMK,AA0"
633   ENTER 711 ; TEMP_A
634   DISP "TEMP_A LINE 6915";TEMP_A
635   G_MEAS=TEMP_A*ACCEL_SENSE/GAIN_A
636   DISP "G MEAS:";TEMP_A*ACCEL_SENSE/GAIN_A
637   WAIT 2000
638   DISP
639   RETURN

```

```

640 ! *****
641 ! ***** MEASURE_Gs_ADJ_VOLTAGE *****
642 ! *****
643 MEASURE_Gs_ADJUST_VOLTAGE:
644     DISP
645     DISP
646     DISP "I AM COMPUTING THE G's OBTAINED AND WILL SEE IF "
647     DISP "THE MEASURED G IS WITHIN LIMITS SPECIFIED. IF NOT"
648 ! Records values obtained on run number 'N'. Moves to next pair.
649     DISP "WITHIN LIMITS A NEW VOLTAGE WILL BE CALCULATED."
650     IF N+1=MAX_TRIES+1 THEN G_MIN=G_MEAS
651 ! Determine if the created g load is within limits specified.
652     IF G_MIN<= G_MEAS AND G_MEAS<= G_MAX THEN RETURN ELSE GOSUB DETERMINE_NEW_VOLTAGE
653 RETURN
654 ! *****
655 ! ***** DETERMINE_NEW_VOLTAGE *****
656 ! *****
657 DETERMINE_NEW_VOLTAGE:
658     X=G_MEAS
659     Y=V
660     IF N>1 THEN GOSUB LEAST_SQUARE_COEFFICIENTS
661     IF N<5 THEN GOSUB LINEAR ELSE GOSUB CUBIC
662     GOSUB VOLTAGE_LIMIT_CHECK
663     GOSUB OUTPUT_FREQUENCY_AND_VOLTAGE
664     GOSUB MEASURE_Gs_ADJUST_VOLTAGE
665     RETURN
666 LINEAR:
667     IF G_MEAS<G_MIN THEN 676 ELSE 689
668     DISP "ATTEMPT :";N;"G_LOAD TOO SMALL "
669     DISP "FOR TEST VOLTAGE :";V;"MILLIVOLTS"
670     CORRECTION=G_REQ(M)/G_MEAS
671     DISP "G_MIN:";;;G_MIN
672     DISP "G_MEAS:";;;G_MEAS
673     DISP "G_REQ(M):";G_REQ(M)
674     DISP "CORRECTION FACTOR:";CORRECTION
675     V=V*CORRECTION
676     IF V<100 THEN V=INT ((V+.05)*10)/10 ELSE V=INT (V-.5)
677     DISP "NEW INPUT VOLTAGE IS :";V;"MILLIVOLTS"
678     N=N+1
679     RETURN
680 !

```

```

681 IF G_MEAS>G_MAX THEN 682
682 DISP
683 DISP "ATTEMPT NO.:";N;"G_LOAD TOO BIG."
684 DISP "FOR TEST VOLTAGE :";V;"MILLIVOLTS"
685 DISP "G_MAX:";G_MAX
686 DISP "G_MEAS:";G_MEAS
687 DISP "G_REQ(M):";G_REQ(M)
688 CORRECTION=G_REQ(M)/G_MEAS
689 DISP "CORRECTION FACTOR:";CORRECTION
690 V=V*CORRECTION
691 IF V<100 THEN V=INT ((V+.05)*10)/10 ELSE V=INT (V+.5)
692 DISP "NEW INPUT VOLTAGE IS :";V;"MILLIVOLTS."
693 N=N+1
694 RETURN
695 RESET_COUNTERS_ADDERS:
696 !
697 N=1
698 V=INITIAL_VOLTAGE
699 DISP "RESETTING"
700 DISP
701 SUM_X=0
702 SUM_X2=0
703 SUM_X3=0
704 SUM_X4=0
705 SUM_X4=0
706 SUM_X5=0
707 SUM_X6=0
708 SUM_Y=0
709 SUM_XY=0
710 SUM_X2Y=0
711 SUM_X3Y=0
712 X=0
713 Y=0
714 GOSUB LEAST_SQUARE_COEFFICIENTS
715 RETURN
716 LEAST_SQUARE_COEFFICIENTS:
717 !
718 DISP "SUMMING COEFFICIENTS"
719 !
720 SUM_X=SUM_X+X
721 SUM_X2=SUM_X2+X^2
722 SUM_X3=SUM_X3+X^3
723 SUM_X4=SUM_X4+X^4
724 SUM_X5=SUM_X5+X^5
725 SUM_X6=SUM_X6+X^6
726 SUM_Y=SUM_Y+Y
727 SUM_XY=SUM_XY+X*Y
728 SUM_X2Y=SUM_X2Y+X^2*Y
729 SUM_X3Y=SUM_X3Y+X^3*Y
730 !
731 RETURN

```

```

732 ! *****
733 ! ***** CUBIC *****
734 ! *****
735 CUBIC:
736 DISP "COMPUTING CUBIC COEFFICIENTS"
737 B21=SUM_X*SUM_X-N*SUM_X2
738 C21=SUM_X*SUM_X2-N*SUM_X3
739 D21=SUM_X*SUM_X3-N*SUM_X4
740 T21=SUM_X*SUM_Y-N*SUM_XY
741 B31=SUM_X*SUM_X2-N*SUM_X3
742 C31=SUM_X2*SUM_X2-N*SUM_X4
743 D31=SUM_X2*SUM_X3-N*SUM_X5
744 T31=SUM_X2*SUM_Y-N*SUM_X2Y
745 B41=SUM_X*SUM_X3-N*SUM_X4
746 C41=SUM_X2*SUM_X3-N*SUM_X5
747 D41=SUM_X3*SUM_X3-N*SUM_X6
748 T41=SUM_Y*SUM_X3-N*SUM_X3Y
749 C32=B31*C21-B21*C31
750 D32=B31*D21-B21*D31
751 T32=T21*B31-B21*T31
752 C42=C21*B41-B21*C41
753 D42=D21*B41-B21*D41
754 T42=T21*B41-B21*T41
755 D43N=C42*T32-C32*T42
756 D43D=C42*D32-C32*D42
757 D=D43N/D43D
758 C=(T42-D*D42)/C42
759 B=(T21-C*C21-D*D21)/B21
760 A=(SUM_Y-SUM_X*B-SUM_X2*C-SUM_X3*D)/N
761 DISP "THE 'A' COEFFICIENT =" ;A
762 DISP "THE 'B' COEFFICIENT =" ;B
763 DISP "THE 'C' COEFFICIENT =" ;C
764 DISP "THE 'D' COEFFICIENT =" ;D
765 X=G_REQ(M)
766 V=A+B*X+C*X*X+D*X*X*X
767 IF V<100 THEN V=INT ((V+.05)*10)/10 ELSE V=INT (V+.5)
768 !
769 DISP "NEW VOLTAGE FOR";G_REQ(M);"IS";V
770 N=N+1
771 RETURN

```



```

772 ! *****
773 ! ***** MEASURE_AND_RECORD_FINAL_VALUES *****
774 ! *****
775 ! *****
776 MEASURE_AND_RECORD_FINAL_VALUES:
777 DISP "I AM MEASURING FINAL RESULTS FOR DISPLAY AND RECORDING."
778 DISP
779 WAIT 10000
780 VOLT_I(M)=V
781 G_LOAD1(M)=G_MEAS
782 ITERATIONS(M)=N
783 ! Read FFT channel B to obtain test item voltage.
784 ! Turn channel A back on.
785 OUTPUT 711 ; "LMK,AA1"
786 ENTER 711 ; TEMP_B
787 DISP "TEMP_B LINE 8450";TEMP_B
788 ! Enters FFT chan B voltage in millivolts and takes into account
789 ! preamp gain.
790 VOLT_B(M)=TEMP_B*1000/GAIN_B ! millivolts
791 !
792 ON SPL_TRANSMISSIBILITY GOSUB TEST_ITEM_SPL ,TRANSMISSIBILITY_DB
793 !
794 ! Begin combining band sound pressure levels.
795 SUM_SPL=SUM_SPL+10^(SPL(M)/10)
796 VB=VOLT_B(M) ! Millivolts
797 PRINT# 1 ; FREQ(M),G_LOAD1(M),VB,ITERATIONS(M),SPL(M)
798 RETURN
799 !
800 TEST_ITEM_SPL:
801 IF VOLT_B(M)=0 THEN SPL(M)=0 ELSE GOTO 803
802 RETURN
803 SPL(M)=20*LGT (VOLT_B(M)/TEST_SENSE)+DB_REF_LEVEL
804 RETURN
805 !
806 TRANSMISSIBILITY_DB:
807 SPL(M)=20*LGT (TEMP_B/GAIN_B/VFG_ISOL/(TEMP_A/GAIN_A/VFG_VIBE))
808 RETURN
809 !

```

```

810 ! *****
811 ! ***** PRINT_INDIVIDUAL_RESULTS *****
812 ! *****
813 PRINT_INDIVIDUAL_RESULTS:
814 ! Some abbreviations.
815 GPV=G_MEAS/V
816 VB=VOLT_B(M)*1000 ! Converted to microvolts
817 SPL=SPL(M)
818 GR=G_REQ(M)
819 GL1=G_LOAD1(M)
820 VA=TEMP_A*1000/GAIN_A
821 DISP USING 822 ; "FREQ","ITEM","SPL/","INPUT","ACCEL",R$,O$,N$
822 IMAGE 10X,4A,4X,5A,3X,5A,2X,5A,3X,5A,2X,5A,4X,3A,5X,3A
823 DISP USING 824 ; V$,"XMISS",V$,V$,"G LOAD","G LOAD","TRIES"
824 IMAGE 18X,5A,2X,5A,3X,5A,3X,5A,2X,6A,2X,6A,2X,6A
825 DISP USING 826 ; "(HZ)","(uV)","(DB)","(MV)","(MV)","(G's)","(G's)"
826 IMAGE 10X,4A,4X,4A,4X,4A,4X,5A,3X,5A,2X,5A,2X,5A
827 DISP USING 828 ; FREQ(M),VB,SPL,V,VA,GR,GL1,ITERATIONS(M)
828 IMAGE 10X,4D.D,2X,4D.D,2X,3D.DD,X,4D.D,3X,D.3D,3X,D.DD,3X,D.DD,5X,2D
829 PRINT USING 830 ; FREQ(M),VB,SPL,V,VA,GR,GL1,ITERATIONS(M)
830 IMAGE 10X,4D.D,2X,4D.D,2X,3D.DD,X,4D.D,3X,D.3D,3X,D.DD,3X,D.DD,5X,2D
831 RETURN

```

```

832 ! *****
833 ! ***** PRINT_OVERALL_RESULTS *****
834 ! *****
835 PRINT_OVERALL_RESULTS:
836 !   Compute overall band SPL
837   OVERALL_BAND_LEVEL=10*LGT (SUM_SPL)
838 !
839   WAIT 6000
840   CLEAR
841   DISP "OVERALL BAND SOUND PRESSURE LEVEL:";OVERALL_BAND_LEVEL
842   PRINT USING 843 ; "OVERALL BAND SPL:";OVERALL_BAND_LEVEL;"DB. REF LEVEL";TEST_SENSE;"mV @";DB_
REF_LEVEL;"DB."
843   IMAGE /,10X,17A,4D.D,X,14A,4D.DD,4A,X,DDD,X,3A
844 PRINT
845 PRINT USING 855 ; "COMMENTS:"
846 PRINT
847 PRINT USING 850 ; "SPL/XMISS: READ 'SPL' FOR MEASURED VOLTAGE RESPONSE."
848 PRINT USING 851 ; "READ 'XMISS' FOR MEASURED TRANSMISSIBILITY."
849 PRINT USING 852 ; "G LOADS OBTAINED WERE WITHIN";T;"% OF DESIRED VALUES."
850 IMAGE 10X,60A
851 IMAGE 21X,50A
852 IMAGE 10X,28A,DD.D,20A
853 PRINT USING 855 ; "ALL VOLTAGES ARE WITHOUT AMPLIFICATION AND INCLUDE"
854 PRINT USING 855 ; "LINE LOSSES TO PREAMP."
855 IMAGE 10X,57A
856 ! Print to disk
857 PRINT# 1 ; OVERALL_BAND_LEVEL
858   OUTPUT 707 ; "AF",0,"MV"
859   OUTPUT 711 ; "AAOAB0"
860   DISP "ENTER ANY(60 CHR MAX) COMMENT ABOUT THE RUN JUST COMPLETED."
861 DISP "ENTER";"";" IF YOU HAVE NO COMMENTS. THEN PRESS 'END LINE'."
862 DISP "XXXXXXXXXX COMMENT   LENGTH XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX"
863   INPUT COMMENTS3$
864 !
865   DISP "COMMENTS:";COMMENTS1$&COMMENTS2$
866 PRINT USING 869 ; COMMENTS1$
867 PRINT USING 869 ; COMMENTS2$
868 PRINT USING 869 ; COMMENTS3$
869 IMAGE 10X,60A
870 RETURN
871 ! *****
872 ! ***** CLOSE_FILES_AND_NULL_OUTPUTS *****
873 ! *****
874 CLOSE_FILES_AND_NULL_OUTPUTS:
875   OUTPUT 707 ; "AF",0,"MV"
876   OUTPUT 711 ; "AAOAB0"
877   ASSIGN# 1 TO *
878   CLEAR
879 !
880 RETURN

```

```

881 ! *****
882 ! ***** ANOTHER_RUN *****
883 ! *****
884 ANOTHER_RUN:
885 DISP "IF YOU DESIRE ANOTHER RUN ENTER '1',IF NOT ENTER '2'."
886 INPUT AGAIN
887 WAIT 10000
888 CLEAR
889 ON AGAIN GOTO 893,890
890 DISP "THANK YOU FOR YOUR HELP. SEE YOU TOMMORROW. HP-87."
891 PRINT CHR$(27) & "&K05"
892 RETURN
893 RESET_CONDITIONS:
894 !
895 DISP "CONDITION 1: ITEM AND ALL CONDITIONS REMAIN UNCHANGED."
896 DISP "CONDITION 2: ITEM IS UNCHANGED, CONDITIONS CHANGE."
897 DISP "CONDITION 3: ITEM AND CONDITIONS CHANGE."
898 DISP "IF TEST EQUIPMENT SETTINGS OR PARAMETERS CHANGE "
899 DISP "PRESS 'RUN'."
900 DISP "ENTER THE CONDITION NUMBER DESIRED."
901 INPUT CONDITION
902 IF CONDITION=1 THEN 903 ELSE 915
903 RUN_NO=VAL (RUN_NO$)+1
904 RUN_NO$=VAL$ (RUN_NO)
905 GOSUB CONCATENATE_FILENAME_INPUTS
906 GOSUB SELECT_DATA_ENTRY_METHOD
907 GOSUB PRINT_HEADERS
908 GOSUB CALIBRATE_EQUIPMENT
909 GOSUB TEST_AT_FREQUENCY_6_LOAD_PAIRS
910 GOSUB PRINT_OVERALL_RESULTS
911 GOSUB CLOSE_FILES_AND_NULL_OUTPUTS
912 GOSUB ANOTHER_RUN
913 RETURN
914 !
915 IF CONDITION=2 THEN 923 ELSE 934
916 GOSUB TEST_CONDITIONS_FILENAME_INPUTS
917 GOSUB CONCATENATE_FILENAME_INPUTS
918 GOSUB SELECT_DATA_ENTRY_METHOD
919 GOSUB PRINT_HEADERS
920 GOSUB CALIBRATE_EQUIPMENT
921 GOSUB TEST_AT_FREQUENCY_6_LOAD_PAIRS
922 GOSUB PRINT_OVERALL_RESULTS
923 GOSUB CLOSE_FILES_AND_NULL_OUTPUTS
924 GOSUB ANOTHER_RUN
925 RETURN
926 !

```

```
927   ON CONDITION=3 GOTO 928
928   GOSUB TEST_ITEM_DATA
929   GOSUB DISPLAY_TEST_ITEM_DATA
930   GOSUB TEST_CONDITIONS_FILENAME_INPUTS
931   GOSUB CONCATENATE_FILENAME_INPUTS
932   GOSUB SELECT_DATA_ENTRY_METHOD
933   GOSUB PRINT_HEADERS
934   GOSUB CALIBRATE_EQUIPMENT
935   GOSUB TEST_AT_FREQUENCY_6_LOAD_PAIRS
936   GOSUB PRINT_OVERALL_RESULTS
937   GOSUB CLOSE_FILES_AND_NULL_OUTPUTS
938   GOSUB ANOTHER_RUN
939   RETURN
```

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